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A TIMBER ROT ACCOMPANYING HYMENO- CHAETE RUBIGINOSA (SCHRAD.) LÉV.

(WITH PLATES 149-151, CONTAINING 30 FIGURES)

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The Hymenomycetes among the fungi play the leading rôle in the disintegration and destruction of wood. Since Theo. Hartig's first attempt at the scientific investigation of the decay of wood in 1833,⁸ other workers have contributed from time to time and as a result an extensive literature on this phase of mycology has been gradually collected.

Of the investigated forms, the Polyporaceae have been most extensively studied. This is due in part at least to their large, conspicuous fruit bodies and the obvious relation between them and the decay resulting in the wood. Many other Basidiomycetes as well as Ascomycetes are wood-inhabiting, and interesting results have already been obtained from studies of isolated forms in various families. The field of research may be divided into two lines of effort; to secure definite data on the chemical composition of wood in general and of changes resulting from decay, and to augment our present field of knowledge of the decay of wood by a study of uninvestigated wood-inhabiting forms. The present study of *Hymenochaete rubiginosa* (Schrad.) Lév. was undertaken with the latter point in mind.¹

¹ This work was carried on in the Botanical Laboratory of Cornell University under the direction of Prof. Geo. F. Atkinson, to whom the writer is indebted for the suggestion of the problem and for advice.

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Hymenochaete rubiginosa is a common saprophyte on decorated chestnut in the vicinity of Ithaca, N. Y., and is also found more rarely on decorticated oak. The brown, resupinate or dimidiate fruit bodies (Figs. 1, 3), rarely over four or five centimeters in diameter, are usually to be found where oak and chestnut timber lies on the ground in the forest. Chestnut-rail fences which extend into the deep shade of the woods present an ideal place for its collection and almost invariably the lowest rail, partially immersed in leaf mold, is infested with the fungus. Where the rail is oblique to the surface of the ground and one end is imbedded in the humus, thereby insuring a sufficient supply of moisture, the fruit bodies may be entirely resupinate and reflexed. On fallen trunks they usually become dimidiate and often hollow-ungulate, the pilei imbricated, irregularly united and sharply oblique to the substratum. When mature, the shelving pilei are smooth above, except for the pubescent margin, and exhibit fine concentric lines on their upper surface. These are not the result of perennial growth, since the fruit bodies are annual, but rather of fluctuations in seasonal growth brought about by varying amounts of moisture. The fruiting surface, or hymenium, of the pilei is glabrous at maturity except at the margin. When viewed with a pocket lens of ten diameters, it is seen to be covered with many brown setae which project upward from the grayish hymenium. It is due to this character that Léveillé¹⁰ first separated such forms from the genus *Stereum*.

Development of the Fruit Bodies.—As already noted, the fruit bodies make their appearance on decorticated wood. Even in collecting several hundred specimens at periods extending over two years, no exceptions were found to the above rule. The fruit bodies rarely appear on wood in an advanced stage of disintegration. A few cases were observed where the wood was badly decayed to a depth of a centimeter under the fruit bodies due to attacks of this or other fungi. In such cases, however, the fruit bodies were always connected with the firm, hard wood in the core of the log. They are never formed from mycelium in wood which has lost its firmness or exhibits advanced stages of decay.

The first evidence of the formation of fruit bodies is the appearance of small, brown, mycelial wefts on the surface of the

infected wood. These are usually discoid in shape and about the size of the head of a pin. More rarely, narrower brown areas occur which are elongated lengthwise of the log. In such cases the hyphal wefts arise from seasoning checks in the wood; the first case is by far the most frequent. Usually several, or as many as a dozen, of these small brown disks arise in the area of a square inch.

The manner of growth of the brown disks, once formed, depends on their position with reference to the substratum. If they occur laterally on a log, dimidiate fruit bodies are formed; if on the under side, wholly resupinate forms arise. In either case, growth goes on all along the margin of the disk for a time. Subsequently, in the dimidiate forms, the upper margin continues its growth, arches out away from the substratum, and forms the pileus. The lower margin continues to expand for a short time downward along the substratum and may unite with other fruit bodies, but eventually, and much sooner than the arching upper margin, ceases to grow. The final result is a cluster of shelving fruit bodies, partially coalesced behind next to the substratum, but with separate free outer margins.

The development of the wholly resupinate forms is easier to follow. Growth is much more regular along the margin and may continue so evenly that circular fruit bodies are formed. Usually, however, owing to the irregularities of the substratum, growth is restricted here and there so that the contour of the fruit bodies becomes irregular and sinuous. This appearance is still further enhanced because the fruit bodies often coalesce (Fig. 21). Two advancing margins meet and the hyphae intermingle. The line of union remains distinct for a time as a pubescent ridge through the hymenium, but eventually the latter covers this and the line of delimitation between the two fruit bodies is obliterated. In this way, extended hymenial layers are formed in the resupinate type. Evidence of their synthetic origin may be observed, however, by carefully removing them from the substratum and examining the surface next to the wood. In such a case, one finds as many points of attachment as there are units entering into the structure of the compound sporophore.

Age of Fruit Bodies.—The fruit bodies of *Hymenochaete rub-*

iginosa are annual. Growth may go on at the margin until well into the autumn and as a result an increase in surface area occurs, but in no case was a new hymenial formation found the following spring. After the first season, the hymenial surface loses its rich rubiginous color and becomes dull and grayish-brown. As the fungus dries out, as happens in many cases, extensive checking occurs. The fruit bodies of the season are readily discernable from those of former years because of the differences enumerated above.

The fungus is essentially a xerophyte. It withstands to a remarkable degree the many vicissitudes of climate and recovers well after a prolonged drought. Within a few hours after precipitation, spore formation begins again and continues as long as favorable conditions prevail. Interrupted spore formation may go on in this way during the summer and autumn.

The time at which fruit bodies first begin to shed spores varies with conditions. Fruit bodies with a surface area of a square centimeter were found to be producing viable spores, and it is possible that spore formation may have begun when they were much smaller. Spore formation begins before the fruit bodies have attained their ultimate size and continues with many interruptions until late autumn.

Structure of the Fruit Bodies.—There are three distinct layers discernable (Fig. 18), which give to the fruit body a stratose structure. The lower exposed layer bears the hymenium on its outer surface and makes up the greater part of the thickness of the fruit body (Fig. 4) and its limits of variation are such that a fruit body may be fully twice as thick in some places as in others. The second layer consists of a narrow stratum of hyphae near the upper surface, closely entwined and fastened together. The third and last is a loose, floccose stratum of hyphae, in which the course of the filaments as individuals may be readily followed. The last two layers exhibit little variation in thickness.

The hymenium of the species under consideration (Fig. 19) consists of three distinct structures, viz.: large and prominent brown cystidia (*a*), colorless basidia (*b*), and a third element similar to the basidia, but shorter and only slightly enlarged at the tip (*c*). These may be immature basidia which subsequently

elongate and produce spores. This conclusion is plausible because spore formation continues for a long period and careful examination of fruit bodies during the summer and autumn has shown that the spores produced by a basidium mature at approximately the same time.² It follows that the basidia probably develop successively during moist periods, a condition which accounts for the continued spore formation.

The large, brown setae vary in shape from conical-acute to bluntly cylindrical and measure 70-100 μ by 4-5 μ . Below, they taper gradually into thin-walled hyphae which extend horizontally. Massee¹¹ makes note that in addition to the normal setae, stout cylindrical, obtuse, thin-walled, pale-brown bodies, intermediate between setae and cystidia, are sparingly met with in the hymenium. A careful microscopical examination of a number of specimens failed to reveal such structures in the form common about Ithaca, N. Y.

The basidia are approximately one third the length of the cystidia and are quite colorless. They are attached below to brown hyphae.

The spores are hyaline, ellipsoidal, and measure 5.5-6.4 μ long by 2.8-3 μ broad (Figs. 2, 17^a). These dimensions conform closely to the spore measurements by Massee, who gives them as $5 \times 3 \mu$ for this species. Saccardo¹⁴ in his description says "sporis cylindraceis, curvatis, 5-6 μ long." The spores of specimens found about Ithaca correspond in length, but are neither cylindrical nor curved. Spores taken from a number of fruit bodies all proved to be ellipsoidal.

Spore Germination.—Spores were obtained from many different specimens through a period of two years. The fruit bodies as brought in from the field were placed in moist chambers over sterilized petrie dishes, and the spores obtained in this way were preserved for further study.

Spore germination was attempted in Van Tieghem cells which had been carefully sterilized previously with 5 per cent. corrosive sublimate solution and rinsed in distilled water. Mounts were then made, using tap water, distilled water, filtered chestnut

² H. M. Ward¹⁸ has described and figured similar structures in the hymenium of *Stereum hirsutum* Fr. and has suggested further that these intermediate hyphae may grow forward to develop a new hymenial layer.

wood extract, prune decoction and a solution of beef extract and malt.³ The best germination was obtained with chestnut wood extract. Slight germination occurred in tap water and in the malt beef extract; the others gave negative results.

Before germination, or with its inception, the spore becomes vacuolate (Figs *b* and *e*). Then germination occurs at one or both ends. Lateral germ tubes were not observed. A small papilla, always of smaller diameter than the spore, is formed, which gradually elongates to form the germ tube. At the end of forty-eight hours, some of the germ tubes attained a length of from four to six times the length of the spore (Fig. 8). Thereafter growth was very slight. In preparations a week old, here and there a germ tube had branched, but in general only slight elongation occurred after the second or third day. Mycelial wefts were not obtained in hanging drop cultures. Rarely one or two cross walls were formed in the germ tube, but these were never accompanied by clamp connections.

An earnest effort to secure pure cultures of the fungus led to no tangible results. Various media were tried, among which may be enumerated prune agar, bean agar, chestnut wood decoction agar, chestnut wood decoction gelatin, corn meal moistened with wood decoction, corn meal moistened with tap water, sterilized chestnut wood, sterilized oak wood, bean tubes, potato tubes, carrot tubes, and a medium made after Marpmann's formula.⁴ Inoculations were made with newly fallen spores and with germinating spores from hanging drop cultures. A sparse, floccose mycelium from germinating spore infection was formed in the bean tubes, but the hyphae were always restricted in their growth. Attempts to transfer these colonies to more favorable media resulted in failure. New experiments are now under way with this object in view, and it is to be hoped that they may be more fruitful of results. The timber rot accompanying the fruit bodies

³ $2\frac{1}{2}$ gm. Liebig's beef extract¹³, $2\frac{1}{2}$ gm. Lofflund's malt extract, 100 c.c. water.

⁴ Dissolve by cooking 10 gm. of gelatin and 10 gm. of agar in 500 gm. of beef extract; then add to the solution 10 gm. glycerine, 10 gm. salt, 5 gm. ammonium phosphate, and 4 gm. potassium nitrate; filter.

of this fungus on chestnut and oak, compared with the condition of the normal wood, may now be described.⁵

Character of Normal Wood.—The wood of chestnut is of the ring-porous type.¹² There are several rows of large vessels in the spring wood out of which branching rows of smaller vessels extend radially into the summer wood. The transition from large to small vessels is usually very abrupt (Fig. 6) and the radial arrangement of the small vessels is often somewhat obscure. Annual ring formation is pronounced, each ring being sharply delimited from the others. The width of the ring varies within wide limits; sometimes in coppice growth it is over half an inch in thickness. The pith rays are minute and scarcely distinguishable with the naked eye.

Microscopically the wood of chestnut is seen to consist of (a) uniseriate pith rays, (b) pitted vessels, (c) metatracheal parenchyma with simple or semi-bordered pits, (d) tracheids and (e), wood fibers. The last are not typical fibers, but of the nature of fibrous tracheids.⁶ The vessels are discernible in cross section by their size. Fibrous tracheids, tracheids, and wood parenchyma look much alike; the last may be distinguished, however, through its protoplasmic contents. The vessels exhibit the greatest variation in size in the annual ring. The cell lumina of the parenchyma and prosenchyma are somewhat wider in the spring wood than in the summer wood, but show no great range of variability in actual size.

Description of Decay in Chestnut.—The first evidence of incipient decay in chestnut wood is the appearance in the wood of irregular areas in which the tissues have lost their natural brown coloration and become grayish-white (Fig. 5, 10). These areas are 1 mm. or less in cross diameter by 5-25 mm. in longitudinal direction. The wood between the lighter areas remains as sound

⁵ Direct evidence of the causal connection of *Hymenochaete rubiginosa* with the peculiar rot which accompanies it, has not been obtained in the present study. It is reasonable to assume that the rot in question is caused by this species since it always accompanies this form on chestnut. Further, the same type of rot is associated with this fungus on oak. This evidence, though not conclusive, leads to the inference that this peculiar decay of oak and chestnut is caused by *H. rubiginosa*.

⁶ In length and taper, fibrous tracheids resemble fibers; in width and bordered pits, tracheids.

apparently as ever.⁷ Logs, limbs an inch or more in diameter, rail fences, chestnut posts and structural chestnut timber may be attacked. The infection at the start is a local one, and the diseased areas first occur in the last few rings. In such cases they are next to the ground, or with large logs on the lateral side most protected from drought. Only in an advanced stage is the whole cross section attacked, and before this condition is reached the inroads of the fungus are usually arrested through lack of moisture. Chestnut is very durable in contact with the soil, and it is not uncommon to find fallen decorticated limbs and branches showing the decay described above on the lower side, while they are as sound at the core and on the upper side as normally. Only where sufficient moisture is available is the center of the log attacked. Cracks due to checking and frost action greatly facilitate the action of the fungus, since they permit the ready ingress of water into the deeper-lying tissues (Fig. 28).

All parts of the annual ring are susceptible to the attacks of the fungus (Fig. 14). The white areas of varying extent and irregular outline may include within their boundaries one or more vessels in the spring wood, or be entirely confined to the outer portion of the ring. The last is usually most severely attacked, however. Occasionally infected spots coalesce and form large areas, although they usually remain free from the start.

At first there is no disintegration in the wood other than the formation of the irregular white areas. The elements retain their original size, thickness, and continuity with one another. Subsequently near the center of the white areas a small cavity appears (Fig. 6). This is bounded at first by white tissue on all sides and includes but a small portion of the diseased area. The white tissue at the margin remains undisturbed.

Within the cavity itself, disintegration is not complete. It is filled with long, white, fibrous elements which remain loosely attached or entirely free from one another. These are thick-walled and offer great resistance to the dissolving action of the fungus. The cavities gradually enlarge as the disintegration goes on until finally all that remains of the original white area is a narrow

⁷ The whole mass of tissue is never affected as in the case of some forms 12, 16, and the wood never loses completely its firmness and elasticity.

boundary line about an enlarged cavity filled with isolated or loosely bound white fibers (Fig. 12). The wood between the cavities retains its original color and is, to all appearances, as sound as ever. In age the white contents and lining of the pockets may disappear and the wood presents the appearance of Figure 9.⁸

In order to trace the progress of the decay in the wood, the following methods were employed. Diseased wood was cut into blocks of convenient size, which were then boiled to fix the hyphae. The air remaining in the tissues was exhausted with an air pump and the blocks were finally imbedded in celloidin in the usual manner. Sections 10 microns thin were used.⁹

A microscopical examination of the wood reveals the action of the fungus to better advantage. In the infected areas the

⁸ Another type of decay was observed in the wood near the surface of the logs which exhibited in the deeper-lying tissues the characteristic decay already described. For a distance of several millimeters inward from the surface, the tissue had turned dark-brownish-black. Whether this decay was caused by the same fungus as that in the deeper-lying tissues was not determined. A species of *Dasy cypha* was frequently found accompanying the *Hymenochaete* and this may have been responsible for the second type of decay.

⁹ In preparing sections for microscopic study both temporary and permanent mounts were made. The first were employed to observe through microchemical reactions the chemical changes in the wood brought about by the fungus. Among the lignin tests which were used may be enumerated the HCl-phloroglucin reaction, the $KClO_3$ -HCl-phenol reaction, aniline sulphate and H_2SO_4 , and thallium sulphate in equal mixtures of water and alcohol.¹⁰ The cellulose tests included chlor-zinc-iodide, sulphuric acid, I-KI and iodine followed by sulphuric acid.

The sections used for permanent mounts were stained in several different ways, viz.: Delafield's haematoxylin and aniline safranin, Haidenhain's haematoxylin and safranin, Haidenhain's haematoxylin and methyl green, 20 per cent. aq. tannic acid and methyl violet, ruthenium red and methyl green. The last two stains enumerated gave the best results with the preference in favor of the methyl violet.

In staining with methyl violet, the material was first treated with a twenty per cent. aqueous solution of tannic acid for twelve hours. It was then quickly rinsed with water and transferred directly to a one per cent. solution of methyl violet for three minutes. The excess stain was removed with 95 per cent. alcohol and the material was finally cleared in clove oil. Only the hyphae in the tissues retained the stain.

The method pursued with ruthenium red and methyl violet was that recommended by Eisen⁴. It has also been described in a recent paper by Learn⁹ and does not require further explanation here because no deviations were made from the prescribed formula.

hyphae run vertically in the cell lumina and are closely applied to the tertiary wall. In cross section (Figs. 22 and 26) they appear as small black dots within the cell cavity. Viewed in longitudinal section each element is seen to contain from several to many hyphae which extend vertically from cell to cell and penetrate the walls at will. Preference is shown for the pits on the walls as in the case of some other forms (Figs. 27 and 29), but the avenues of penetration are by no means restricted to the pits. The hyphae pass directly through the wall with little or no constriction (Fig. 23). Subsequently the perforations thus arising are further enlarged through enzyme action so that the hyphae appear to pass through openings much too large for them. In an advanced stage of decay only the openings are left as the hyphae disappear (Figs. 25 and 30). Nests of hyphae also accumulate in vessel cavities, but the centers of infection are usually in areas where only parenchyma and fibrous tracheids occur. Where pith rays cross the diseased areas, they are attacked and eventually destroyed.

Chemical Changes in Chestnut Wood.—The first chemical change which is brought about by the fungus is that of delignification. It is due to this action that the elements lose their normal brown color and become white. The fungus probably secretes dissolving enzymes which attack the tertiary layers first and work outward. The compounds which are known collectively as lignin are entirely dissolved and walls of pure cellulose left behind. Near the center of infected areas all stages in the process of delignification are to be found (Fig. 26). In the sound cells just without the diseased tissue, all three cell layers respond to tests for lignin (Fig. 22 c), although the tertiary layer appears to be less strongly lignified than the others. The elements nearer the center of infection are already partially delignified (b). In some the tertiary layer no longer gives the lignin reaction, or but feebly, while in others the secondary and primary layers have become involved and delignified. The lignin reaction persists longest at the cell corners where the wall is thickest, or about the small intercellular spaces which often occur there, but even here it disappears eventually, and the tissue that remains consists of almost pure cellulose.

As soon as the middle lamella is delignified, the cells separate

from one another (Fig. 26 c). Whether the middle lamella dissolves or splits is difficult to decide, but it would appear that the former is the case, in that ruthenium red failed to reveal any trace of the middle lamella where the elements had separated. No eroding action of the fungus is to be noted at this stage. The infected area is filled with a mass of white cells, in part free from one another, or loosely joined at the corners where the middle lamella has persisted.

Before the changes above enumerated have taken place in all the outer cells of the infected areas, further alterations usually occur in the elements first infected. The cellulose walls now undergo digestion (Fig. 11), probably in the usual way through the secretion of cytolytic enzymes.¹⁰ The vessels, parenchyma cells and pith ray cells together with the thin-walled prosenchyma are almost entirely dissolved (Fig. 20). The thicker-walled prosenchyma persists the longest, and after the other elements have disappeared remains as a white fibrous structure partially filling and lining the cavities that have arisen. The abundance of these fibers depends in a large part upon the cytolytic activities of the fungus. The dissolving action may go on in extreme cases until the pockets are quite empty of contents, but usually, for reasons which cannot be satisfactorily explained, the activities of the fungus are inhibited before this condition is reached.

The conditions met with in the dark-brown peripheral tissue, previously described, are quite different from those enumerated above. All the cells here have been attacked and partly digested (Fig. 7). Many hyphae are to be seen in vertical view closely applied to the cell walls and the latter fail to respond to either the phloroglucin-HCl or the chlor-zinc-iodide reaction. R. Hartig⁷ noted the same condition in his study of *Merulius lacrymans*. It is possibly explained on the supposition that the fungus has dissolved out but a part of the lignin, and that the portion remaining conceals the chlor-zinc-iodide reaction for cellulose. The periph-

¹⁰ Czapek⁸ considers lignified walls as made up of a hadromal-cellulose ester. The attacking fungus may secrete two or more enzymes, among which may be included hadromase and cytase. The first splits off the compound ester and removes the hadromal. The cellulose remaining behind is subsequently dissolved by the cytase.

eral decay is always restricted, however, and does not seem to be important.

Condition of the Wood Between the Pockets.—As previously noted, the wood between the infected areas remains unaltered chemically and still responds to the various lignin tests. Here and there in a cross section a fungal filament may be seen extending from cell to cell, but the tissue is usually quite free of ramifying hyphae. In general, delignification occurs only in those tissues where the hyphae extend vertically.

It is obvious that mycelial connection exists between the pockets in the wood. This is brought about in some cases by isolated hyphae which extend horizontally through the tissues. More commonly, however, connecting strands of mycelium (Fig. 24) are formed for this purpose. These, as noted in the figure, consist of a number of filaments closely intertwined and forming a horizontal bridge between the pockets. The strands thus arising extend both radially and tangentially. They cause no chemical alteration in the wood other than that correlated with their penetration, but appear to be a means of spreading the areas of infection horizontally.

Character of Normal Oak Wood.—While closely related botanically to chestnut, oak departs decidedly from the former in the anatomy of its wood. Both possess ring-porous wood with rows of smaller vessels which branch in the outer portion of the ring. The transition from large to small vessels may or may not be decidedly abrupt.¹¹ Annual ring formation is as pronounced as in chestnut. The chief difference between the two woods consists in the presence of large multiseriate pith rays (Fig. 16) in oak wood accompanying the smaller uniseriate rays. Contrasting the two genera, oak has two kinds of pith rays, chestnut one.

When examined microscopically, the wood of oak is found to consist of the same elements as those of chestnut. There are several anatomical differences worth noting, however. The vessels have thicker walls. The parenchyma in oak is more abundant and makes up a greater proportion of the wood. There is an abrupt transition from tracheids to wood fibers, and fibrous tracheids do not occur. The tracheids possess bordered pits; the

¹¹ Abrupt in white oak, gradual in live oaks and red oaks.

fibers narrow, oblique, simple pits.¹² This is in strong contrast to the chestnut where all gradations between tracheids and fibers occur, and the latter are characterized by bordered pits of the usual type. Further, the fibers in oak have thicker walls and are more strongly lignified.

In tangential section (Fig. 13) the two types of pith rays are easily discernible. The multiseriate rays appear as broad fusiform structures extending for several millimeters in a vertical direction, while interspersed between them and far surpassing them in number, are the small uniseriate rays. The latter are shorter than those in chestnut.

Description of the Decay in Oak.—The decay of oak associated with *Hymenochaete rubiginosa* is similar to that of chestnut. White areas of varying extent and irregular outline are formed (Figs. 13, 16 a), which extend a millimeter or less across the grain, but often a centimeter or more longitudinally. These subsequently give rise to cavities or pockets lined and partially occluded with white fibers. After this stage further disintegration ceases and the wood appears sound except for the presence of many pockets scattered quite regularly through it. The wood of chestnut and oak never becomes soft and badly disintegrated in this type of decay, but the fungus exhibits a remarkable similarity of action on these two hosts.

The effect of the mycelium of *Hymenochaete rubiginosa* on the wood of chestnut and oak is comparable in its grosser aspects to that of *Trametes abietis* Karst. on the red spruce,¹ and the "partridge" wood of oak caused by *Stereum frustulosum* (Pers.) Fr.¹³ In each case the areas of disintegration are at first localized. The elements of the wood within the infected areas are wholly or in part dissolved and cavities arise which are lined with a layer of almost pure cellulose, and remains of delignified elements.¹⁴ In

¹² It is held by some that all prosenchyma is equipped with bordered pits. The "so called" oblique simple pits in the fibers are interpreted as flattened bordered pits which have been spirally stretched.

¹³ Described by R. Hartig⁶ as *Telephora perdix*.

¹⁴ Weir¹⁸ has recently published a description of a new fungus, *Fomes putearius* Weir, in which the decay is similar to that of *T. Pini* Fr. The lignin reduction, however, is on a much larger scale and the cellulose pockets are frequently two inches in length and vary in breadth according to the structure of the host.

the case of *Trametes abietis* the wood between the original areas of infection is finally attacked and broken down so that the whole mass of wood tissue eventually loses its firmness and is in large part destroyed. The same does not apply to the other fungi mentioned since the cells remain intact and sound between the diseased areas so far as can be detected by microchemical reactions.

The similarity between *Stereum frustulosum* and *Hymenochaete rubiginosa* in their manner of attack and effect on the wood is striking. Both are xerophytic fungi and attack decorticated wood which is sound or little decayed through the attacks of other fungi. The first is a perennial form reported on oak alone, so far as I have observed, the second an annual form found on oak, chestnut, and several other hosts. The first evidence of attack in both is in the formation of white areas which respond to the tests for cellulose. Subsequently the elements in these are in part digested and cavities are formed which in one stage of the disease are lined with a white layer of cellulose. The wood remains sound between the diseased areas and in the final stage the condition resulting is comparable to a honeycomb in which the cavities of the wood represent the chambers in the comb, and the tissue lying between, the walls of the chambers. The white lining has entirely disappeared at this stage.

From the preceding paragraph it follows that the decay in oak associated with *H. rubiginosa* is very similar, superficially, to that caused by *Stereum frustulosum*. Closer examination of the specimens at hand, however, has revealed a difference which may be of value in separating these two types of rot. The flecks caused by *Stereum frustulosum* are shorter and wider than those associated with *H. rubiginosa*. In radial view they appear as a rule from oval to elliptical in shape, while those of *H. rubiginosa* are narrow elliptical to long cylindrical. In the final stage of *Stereum frustulosum* the wood is much more porous, due to the large size of the cavities and the small spaces intervening.¹⁵

Chemical Changes in Oak Wood.—What has been said regard-

¹⁵ The differences given above are much a matter of degree, however, and familiarity with the two types of decay is essential in making a reliable diagnosis.

ing the method of attack and chemical changes in the wood for chestnut applies equally well for oak. The first visible evidence of attack is the formation of white areas in the tissue due to the delignification of the elements. The centers of infection lie between the broad pith rays. In the white spots the hyphae run vertically and become closely applied to the walls of the cells. The fungus works from the lumen outwards, and first removes the lignin from the cell walls, leaving pure cellulose behind. As soon as the middle lamella is attacked, the cells separate completely or cling together loosely at the corners where the thicker walls offer more resistance to the fungus. Finally the thin-walled parenchyma cells and the tracheids are entirely dissolved. The thick-walled strongly lignified wood fibers persist the longest. Only a part of them are dissolved, the remainder forming a white cellulose lining and partly filling the cavities (Fig. 15). In the final stage the cellulose lining is entirely lacking.¹⁶

The wood between the infected areas, as in chestnut, remains apparently as sound as ever. Here and there a hypha may be seen extending horizontally from cell to cell, but connection between the pockets is secured mainly, as in chestnut, by strands of mycelium which run radially and tangentially. As previously noted, the centers of infection have their origin between the large medullary rays, while in chestnut they may occur anywhere within the ring. Once started, however, the white areas spread and may include a portion of a compound ray within their boundaries. The decay in oak is comparable to that in chestnut except in minor respects.

The remarkable similarity which has been shown to exist superficially between the decay of oak caused by *S. frustulosum* and that of *H. rubiginosa* is even more striking when a microscopical investigation is made. The walls of the infected elements in both cases are first delignified, beginning with the tertiary layer, and pure cellulose left behind. As soon as the primary layer is reached, it is dissolved and the elements separate. Subsequently cellulose digestion goes on and the thinner-walled elements are entirely dissolved, the thicker-walled fibers disappearing last and appearing for a time as a white layer lining the cavities.

¹⁶ What has been said above concerning the restricted peripheral decay in chestnut applies equally well to oak.

It is of interest in this connection to compare *Stereum hirsutum* Fr. with *Hymenochaete rubiginosa* in its method of attack on wood and the chemical changes involved (Ward, 1898). This form is not so exacting as to its host as *H. rubiginosa*, but grows readily on oak, willow, horse-chestnut, pine, and other hosts. The fungus, while usually saprophytic, may spread from dead wood into the trunk and in such cases shows marked preference for the sap wood. This does not apply with *H. rubiginosa*; it is found uniformly on fallen, decorticated wood and no preference is shown for sap wood. The mycelium of *Stereum hirsutum* attacks all the elements in the diseased tissue with equal ease and localized areas of distintegration are not formed. The whole mass of tissue eventually succumbs and a general decay of the wood results. In both fungi the first evidence of decay is one of delignification. The tertiary layers are first reduced to cellulose, followed successively by the secondary and primary layers, and the swollen cellulose matrix is then consumed, layer by layer. In the case of *S. hirsutum*, the primary lamella is not attacked until the last, and before it succumbs the tertiary and secondary layers have usually entirely disappeared. This is in marked contrast to the decay caused by *H. rubiginosa*, where the middle lamella disappears as soon as lignin reduction is complete and before cellulose digestion has taken place. While closely related botanically, marked differences occur in the decay caused by the two forms.

The superficial type of decay at the periphery of the wood noted above has likewise been observed in connection with *Stereum frustulosum*.¹⁷ The possibility still remains, however, that this may have been caused by the mycelium of another fungus as in the case of the form described in this paper. Pure cultures are necessary to decide this point.

Between the cavities the wood appears sound in both forms of decay. The pockets may enlarge occasionally and coalesce, and larger pockets thus arise. The mycelial strands accompanying the decay described here were likewise described by Hartig in connection with *Stereum frustulosum*. Both forms apparently employ the same method of attack and bring about a similar progress of decay in the wood.

¹⁷ Hartig, Th., loc. cit., page 19.

SUMMARY

1. *Hymenochaete rubiginosa* (Schrad.) Lév. is a common saprophyte on decorticated chestnut about Ithaca; it is found more rarely on oak.

2. The fruit bodies are annual and quite xerophytic; spores are shed intermittently during moist periods for several months.

3. Spore germination occurs best in decoctions of oak or chestnut sawdust and tap water. Mycelial growth was restricted and clamp connections were not observed.

4. The first evidence of decay in oak and chestnut consists in the formation of white spots here and there in the wood. Cavities lined with cellulose are formed through the partial or complete digestion of the elements.

5. The tissues between the infected areas remain nearly or quite as sound as in normal wood. Rarely do the pockets coalesce through the digestion of intervening tissue.

6. The chemical action of the fungus consists first in the delignification of the elements attacked. This begins with the tertiary layer and continues outward.

7. Soon after the middle lamella is attacked it is dissolved and the elements separate or remain loosely attached at the corners.

8. Cellulose digestion continues after the elements become isolated. The thin-walled elements including pith ray cells and wood parenchyma are first dissolved.

9. The pockets arising in the wood are at first lined with partially digested elements which consist of pure cellulose. In the final stage the white lining entirely disappears.

10. The decay accompanying the fungus is comparable to that caused by *Trametes abietis* Karst., on red spruce and other conifers. It has a remarkable resemblance in superficial appearance and method of attack to that caused by *Stereum frustulosum* (Pers.) Fr.

11. A superficial, peripheral type of decay, in which all the elements are attacked but not entirely digested, usually accompanies the typical decay caused by *Hymenochaete rubiginosa*. The walls remaining are dark in color and fail to respond to the cellulose reaction.

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EXPLANATION OF PLATES CXLIX-CLI

Plate CXLIX

Fig. 1. Dimidiate fruit bodies of *Hymenochaete rubiginosa* (Schrad.) Lév. on a chestnut log. $\times 1/9$.

Fig. 2. Ellipsoidal spores of *Hymenochaete rubiginosa*.

Fig. 3. Resupinate fruit bodies on a chestnut log. $\times 2$.

Fig. 4. Section of fruit body, hymenial surface above.

Fig. 5. Cross section of small chestnut log showing white areas characteristic of one stage of decay. $\times 8/9$.

Fig. 6. Portion of the same enlarged; cavities in process of formation.

Fig. 7. Appearance of tissue in the peripheral type of decay; the hyphae are closely appressed to the cell walls and all the cells are undergoing disintegration.

Fig. 8. Germinating spores in hanging drop culture; note vacuolation in the germ tubes.

Plate CL

Fig. 9. Cross section of small chestnut log showing final stage of decay. $\times \frac{3}{2}$. The contents of the pockets have entirely disappeared.

Fig. 10. Tangential view of pockets. $\times \frac{3}{2}$. The white cellulose contents have not been dissolved.

Fig. 11. Tissue at the edge of a diseased area. Note (a) the delignification of the elements, (b) the separation due to the disappearance of the middle lamella, and (c) final digestion.

Fig. 12. Cross section of chestnut wood showing scattered, irregular-shaped areas where disintegration has occurred. The wood between the pockets is still sound.

Fig. 13. Tangential section of oak wood showing shape of the pockets in side view.

Fig. 14. Cross section of chestnut wood showing a portion of diseased tissue which includes one vessel.

Fig. 15. Same as figure 13. Note the partially digested, thick-walled prosenchymatous elements projecting into the cavity.

Fig. 16. Cross section of oak wood; diseased area on the extreme right (the hazy appearance in the center of the figure is not due to the attacks of the fungus).

Plate CLI

Figures 17-20 are photographs of pen drawings.

Fig. 17. Spores, germination, and germ tubes forty-eight hours after germination.

Fig. 18. Cross section of a fruit body; hymenium above.

Fig. 19. Portion of hymenium enlarged showing cystidia, basidia and spores, and immature basidia.

Fig. 20. Cross section of chestnut wood at margin of diseased area, showing sound cells at *a*, partly delignified cell at *b*, and partly digested cells at *c*.

Fig. 21. Young fruit bodies coalescing to form extensive hymenial surfaces.

Fig. 22. Cross section of chestnut wood at margin of a pocket. The shading indicates the extent of delignification in the cell walls.

Fig. 23. Wood parenchyma cells of chestnut in longitudinal view; hyphae extending horizontally through the pits.

Fig. 24. Mycelial strand extending through the tissue. These serve to connect the pockets which are subsequently formed.

Fig. 25. Pith ray and neighboring parenchyma cells in tangential view. Hyphae have passed through the pits, eroded the cell wall, and then disappeared, leaving irregular openings.

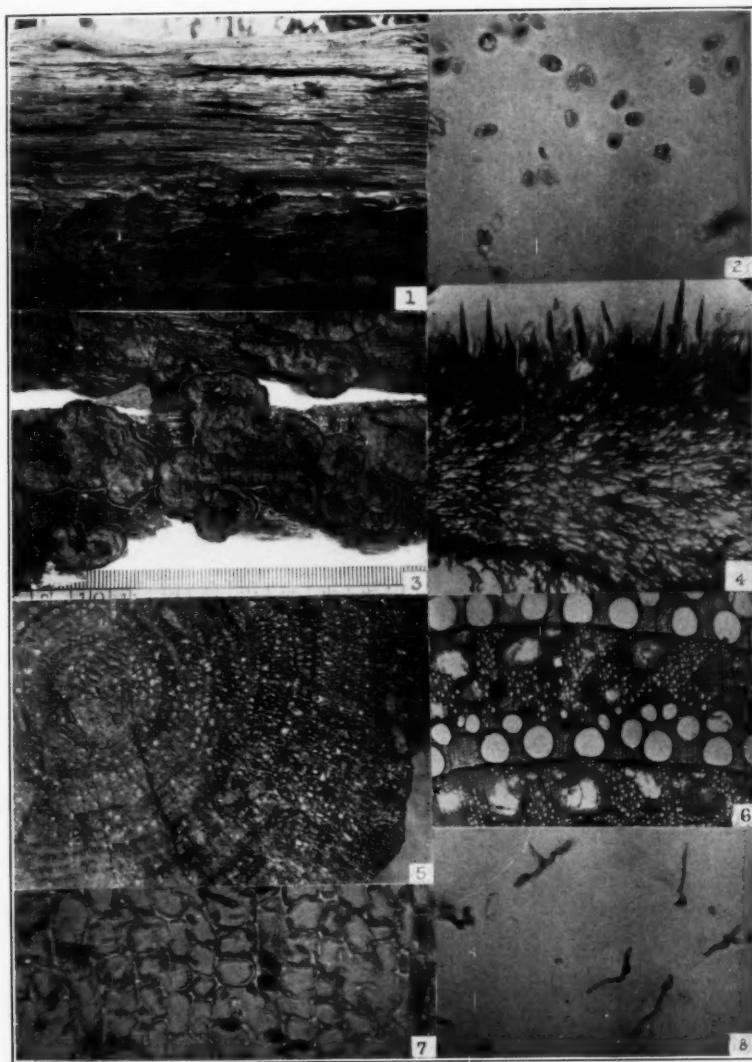
Fig. 26. Cross section of "pocket" in process of formation. The cells have been delignified and have separated from one another.

Fig. 27. Radial view of a pith ray (with other elements in the back-ground) showing the course of hyphae through the wood. Penetration of the wall occurs mainly through the pits.

Fig. 28. Cross section of chestnut log showing seasoning check. The fungus tends to follow these checks into the deeper-lying tissues.

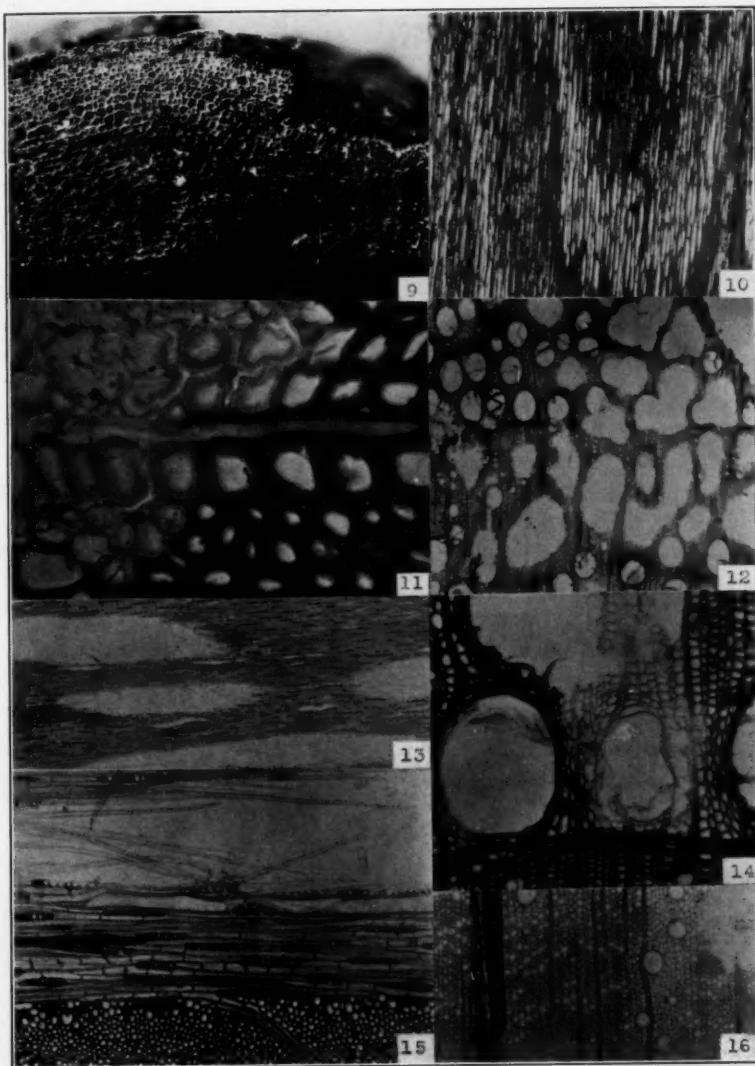
Fig. 29. Radial section of chestnut wood showing fungus filament passing through bordered pits of prosenchyma.

Fig. 30. Portion of pith ray and parenchyma cells of chestnut, tangential section. The intercellular space at (a) and the pits at (b) have been enlarged through fungal attack.



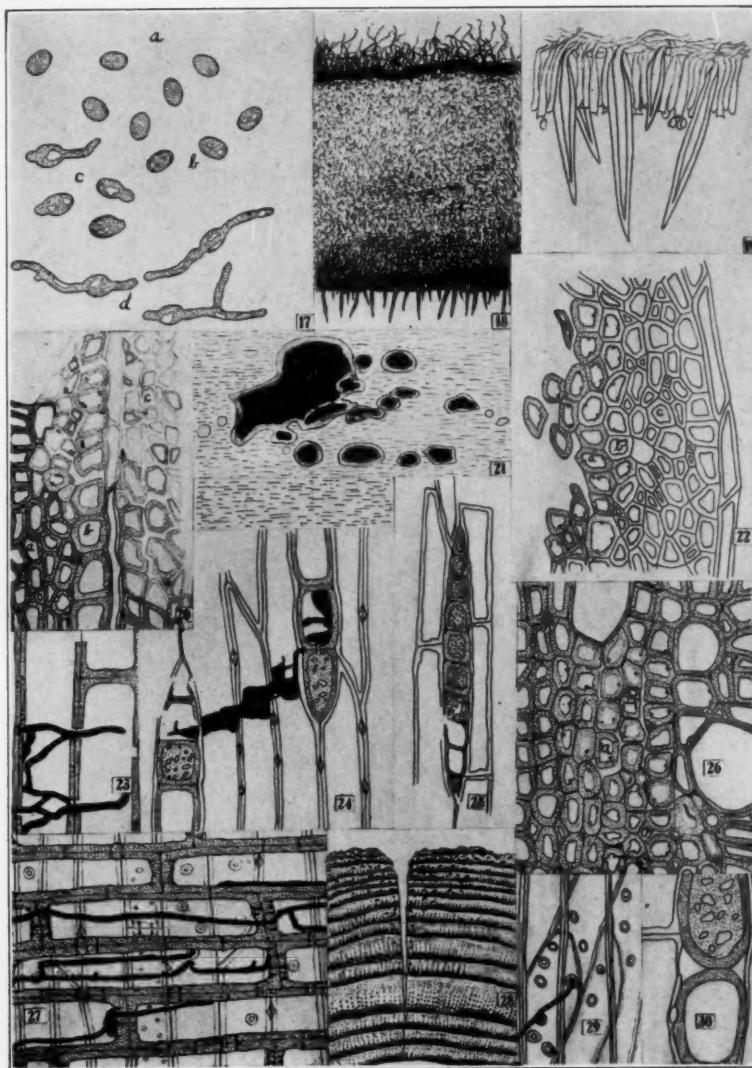
HYMENOCHAETE RUBIGINOSA (SCHRAD.) LÉV.





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STRUCTURAL PARALLELISM BETWEEN SPORE-FORMS IN THE ASCO- MYCETES¹

C. R. ORTON

(WITH PLATE 152, CONTAINING 7 FIGURES)

The term "structural parallelism" is here substituted for the word "homology" which was used when the paper was first presented. There was some objection to the use of the word *homology* and with good reason, for although Brefeld appears to have used the word in a somewhat similar manner, the general use of this conception has been, especially in zoology, not a structural or functional resemblance but a phylogenetic similarity of origin. The similarity which the writer wished to bring out in this paper might be more nearly expressed by the word *analogy* but this implies a functional similarity which, although it may be present, is not precisely what is in mind.

The term *physiological parallelism* was suggested as the general one used to describe similarities like those enumerated in this paper. It seems, however, that even this expression is not strictly appropriate, for the word *physiological* implies again a functional relationship.

The relationship which the writer has in mind is one of a purely structural nature between ascospores and conidia in certain species of Ascomycetes, though similarity in color often accompanies it. Considering the subject purely from this standpoint, the term *structural parallelism* would seem to fit more closely the phenomenon which the writer desires to express in this paper. This appears to be the first time that a study has brought facts of this sort together for this class of fungi, although such a relation undoubtedly has been observed by other investigators.

We are indebted to Tulasne for the early researches among the

¹ Read before the Botanical Society of America at the Atlanta Meeting, December 31, 1913. (Abstract. *Science* 39: 258. 1914.) Contribution from The Department of Botany, Pennsylvania State College. No. 2.

Ascomycetes in which he demonstrated the pleomorphic condition of this class. His researches were based upon the comparison of many forms, their co-habitation, anatomy, and the alternation of their spore-forms. In this way he was able to work out the alternate asexual stages of a number of Ascomycetes.

It may be mentioned that as a result of Tulasne's work a storm of controversy developed which lasted for some time. On the one hand, pleomorphy was considered ridiculous by the most conservative botanists of the time, while on the other hand his results led men of overenthusiasm to ridiculous conclusions.

Owing to the importance of this group on account of its large number of species and their common association with plant diseases, it has occurred to the writer that any constant similarity existing between the conidial and ascigerous stages which might enable an investigator to conclude with some degree of certainty whether two stages are related would be of great assistance. This information would be all the more valuable provided that it was of such a nature that it might be ascertained by a comparative study of the spores.

While the author² was working upon the correlation existing between certain species of rusts his attention was first called to the similarity between conidia and ascospores of certain species of Ascomycetes, the genetic connection of which has been demonstrated. This paper is the result of observations and notes taken from time to time upon such species as may be said to show structural parallelism between their conidia and ascospores.

A similar parallelism between certain spore-forms in the Uredinales has been pointed out by Arthur³, who worked out the connection existing between *Aecidium verbenicola* and *Puccinia Vilfae*,³ *Aecidium Traxini* and *Puccinia peridermiospora*,⁴ and *Aecidium Cephalanthi* and *Puccinia Seymouriana*.⁵ He compared the peculiar morphology of the aeciospores with the same peculi-

² Orton, C. R., Correlation between certain species of *Puccinia* and *Uromyces*. *Mycologia* 4: 194-204. 1912.

³ Arthur, J. C., Cultures of Uredineae in 1899. *Bot. Gaz.* 29: 268-276. 1900.

⁴ Arthur, J. C., The Uredineae occurring upon *Phragmites*, *Spartina*, and *Arundinaria* in America. *Bot. Gaz.* 34: 1-20. 1902.

⁵ Arthur, J. C., loc. cit.

arity possessed by the urediniospores of suspected alternate species and proved by cultures that his presumptions were correct.

It has been pointed out by de Bary⁶ and others that certain species of Ascomycetes on which both conidial and ascigerous stages are known produce mycelium of "the same qualities and capabilities" from both kinds of spores.

There is frequent allusion to this in mycological literature where physiological studies of the mycelium arising from the conidia of a species have been compared with the mycelium arising from ascospores of the known or suspected alternate stage. In one case which has come to my attention a dissimilarity in this respect was considered of sufficient importance to warrant keeping them separated. This view is certainly a safe one to follow, but no one yet has proved in a sufficiently large number of cases that the mycelia from both spores are identical in a physiological test, such as is made in culture media, to justify final conclusions. Such an identity is possible and, if actual, would prove a valuable test to further substantiate the theory of parallelism as herein indicated.

The following examples will serve to bring out more clearly what the writer has in mind. The powdery mildews show this parallelism in every case with which the writer is familiar. Here, there is in the asexual stage the production of simple, colorless, more or less barrel-shaped conidia corresponding almost in every detail with the ascospores of the connected stge.

In the genera *Rhytisma* and *Lophodermium*, which have the conidial forms *Melasmia* and *Leptostroma* respectively, the same likeness is found. In both, the conidia and ascospores are simple, colorless, and cylindrical. The genus *Glomerella* possesses two conidial stages, *Gloesporium* and *Colletotrichum*, each of which possesses conidia structurally similar to the ascospores of *Glomerella*. Still more striking is the similarity between the ascospores of *Ophiocentria coccicola* E. & E. and the conidia of its alternate stage, *Microcera* sp. Both conidia and ascospores are fusoid, colorless, and many-celled. (Fig. 1.)

Herpotrichia nigra has brown, two- to three-septate ascospores

⁶ De Bary, A., Morphology and Biology of the Fungi, Mycetozoa and Bacteria (English edition), pp. 225-230. 1887.

which are so like the conidia of the fungus that if a conidium and ascospore were placed side by side they could hardly be told apart.

Such examples might be multiplied many times but only a few more need be enumerated. *Gnomonia*, *Pseudopeziza*, *Sclerotinia*, *Botryosphaeria*, *Guignardia*, *Cryptospora* and others further considered possess this same parallelism.

One might say that the rule does not hold in certain genera of the Sphaeriaceae where the ascospores are two-celled and the conidia of the alternate stage one-celled. This may be explained in all the cases with which the writer is familiar when one observes the germination of the conidia. For example, the conidia of *Endothia parasitica* are unicellular but germinate and produce mycelium from both ends. Eventually, there are four germ-tubes produced, two from each end of the conidium. This is exactly what happens when the ascospore germinates, two germ-tubes being derived from each cell of the ascospore.⁷ (Fig. 2.) At the beginning of the germination, the conidium sometimes assumes almost the exact shape of the two-celled ascospore of the fungus. However, the interesting condition remains that, so far as germination is concerned, the pycnospores are parallel with the ascospores.

Another condition exists commonly among the species which possess pleomorphic conidial stages, where, of course, one would expect to find only one of the conidial forms similar to the ascospores. Such a species as *Curcurbitaria Laburni* may be cited here. This species is said to have three types of conidia produced successively in pycnidia of varying form. The first two of these conidial stages produce spores which bear no resemblance to the ascospores, but the third and last conidia produced are almost exactly like the ascospores, which are brown and pluricellular-compound. (Fig. 3.) In this case, as well as in genera like

⁷ Anderson, P. J., and Rankin, W. H. *Endothia Canker of Chestnut*. Cornell Agric. Exp. Sta. Bulletin 347: 566-567. 1914. Since this paper was read, the bulletin cited here has appeared. The action of the nuclei during this process of germination can hardly be as Anderson and Rankin have stated, that "the nuclei pass out into the germ tubes almost as soon as they start." If this were literally true, only two germ-tubes could be derived from one spore, as there would be no nuclei left in the spore to give rise to the two later germ tubes which are developed. Evidently, the writers meant to convey the idea that those nuclei which pass out into the tubes do so immediately.

Pleospora and *Apiosporium*, the likeness between the conidia in one stage and the ascospores is very striking.⁸ (Fig. 4.)

A variation of the cases just mentioned, and one which might appear to be an exception, exists in several genera as *Venturia* and *Plowrightia* where the ascospores are two-celled and the conidial stages often unicellular but occasionally two-celled like the ascospores. (Fig. 6.) It might be said here that the mere production of occasional two-celled conidia seems to be of sufficient importance to prove the parallelism, but it is to be noted also that the one-celled spores germinate at both ends and thus function in the same way as does its two-celled companion. This makes the evidence doubly strong that the relationship between conidia and ascospores is very close.

As I have already pointed out, it is manifestly impossible for more than one of the conidial forms of pleomorphic species to be structurally parallel with its ascospores.

Accepting the pleomorphic character of a considerable number of Ascomycetes and allies, why is it not logical to suppose that this condition may be typical of the class and where it fails to appear it may be accounted for by the hypothesis that one or more stages have been lost during the evolution of the group? A majority of the apparent discrepancies in the parallelism of conidia and ascospores may be explained on the supposition that the conidial stages corresponding to the ascospores of the species have been suppressed. This might well be true in such a family as the Hypocreaceae where some of the most apparent incongruities appear. In this family, we find such species as *Nectria galligena*, *N. disco-phora*, and *Hypomyces Ipomoeae*, in which there is no such manifest similarity. On the other hand, however, in this same family, such species as *Gibberella Saubinetii*, *Ophionectria coccicola*, and *Calonectria graminicola* present striking parallelisms. (Fig. 7.)

⁸ Higgins, B. B. Contribution to the Life History and Physiology of *Cylindrosporium* on Stone Fruits. Am. Jour. Bot. 1: 145-173. 1914. Higgins presented at the same meeting at which this paper was read a very interesting case of parallelism in the genus *Coccomyces*, which he has proved to be the ascigerous stage of *Cylindrosporium*. The genus appears to be pleomorphic, at least some species possess three spore stages besides the ascospores. Of the conidial stages, only the *Cylindrosporium* stage appears to function as infection spores and these are almost identical with the ascospores. (Fig. 5.)

There are three possible explanations for these exceptions. *First*, as has just been mentioned, the life history may have become shortened or it may be incompletely known. From the survey of the studies made, this appears to be the most probable condition existing where parallelism fails to appear. *Second*, the supposed conidial and ascigerous stages of a species may have no connection. Numerous instances have been brought to light which show that the original work on the basis of which genetic relationships have been accepted was erroneous. Undoubtedly there are many such assumed connections in this class of fungi. *Third*, the hypothesis falls down completely in certain cases.

While it cannot be said, with our present knowledge of many of the Ascomycetes, that all cases can be made to conform to this theory, yet there seems to be enough evidence presented to show that such a distinct similarity is the rule and that dissimilarity is the exception.

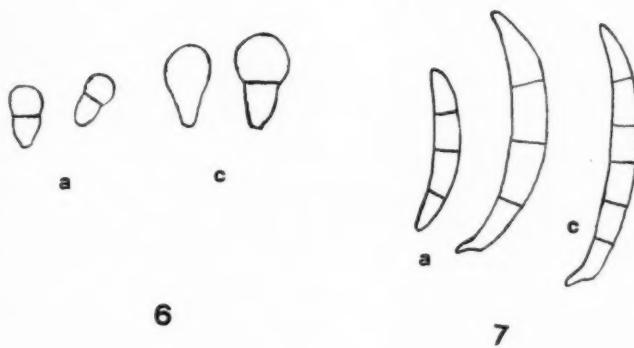
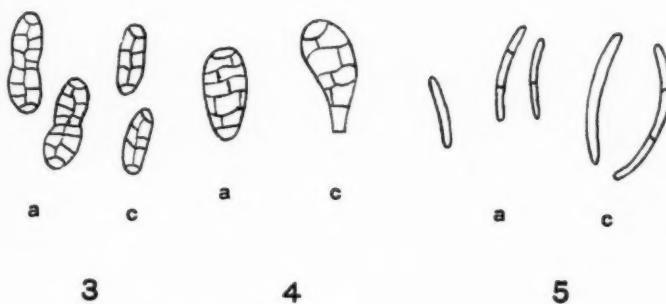
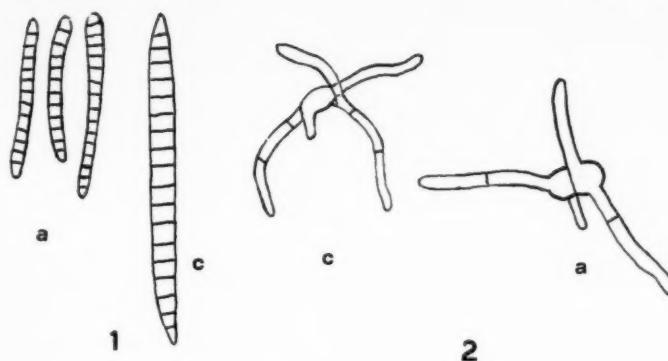
Summarizing these observations, it would seem that among the strictly monomorphic conidial forms of Ascomycetes a rather constant parallelism exists between conidia and the ascospores of the alternate stage; that when one- and two-celled conidia occur, as in *Venturia* and other genera, the ascospores of the alternate stage are generally two-celled; that when the conidia are one-celled and the ascospores two-celled the conidia may in some cases behave as a two-celled spore when they germinate.

Among the pleomorphic conidial species the same likeness probably exists between one of the conidial stages and the ascospores of the alternate stage. Further, it seems probable that when parallelism fails to appear it may be due to abbreviation or to our incomplete knowledge of their life history.

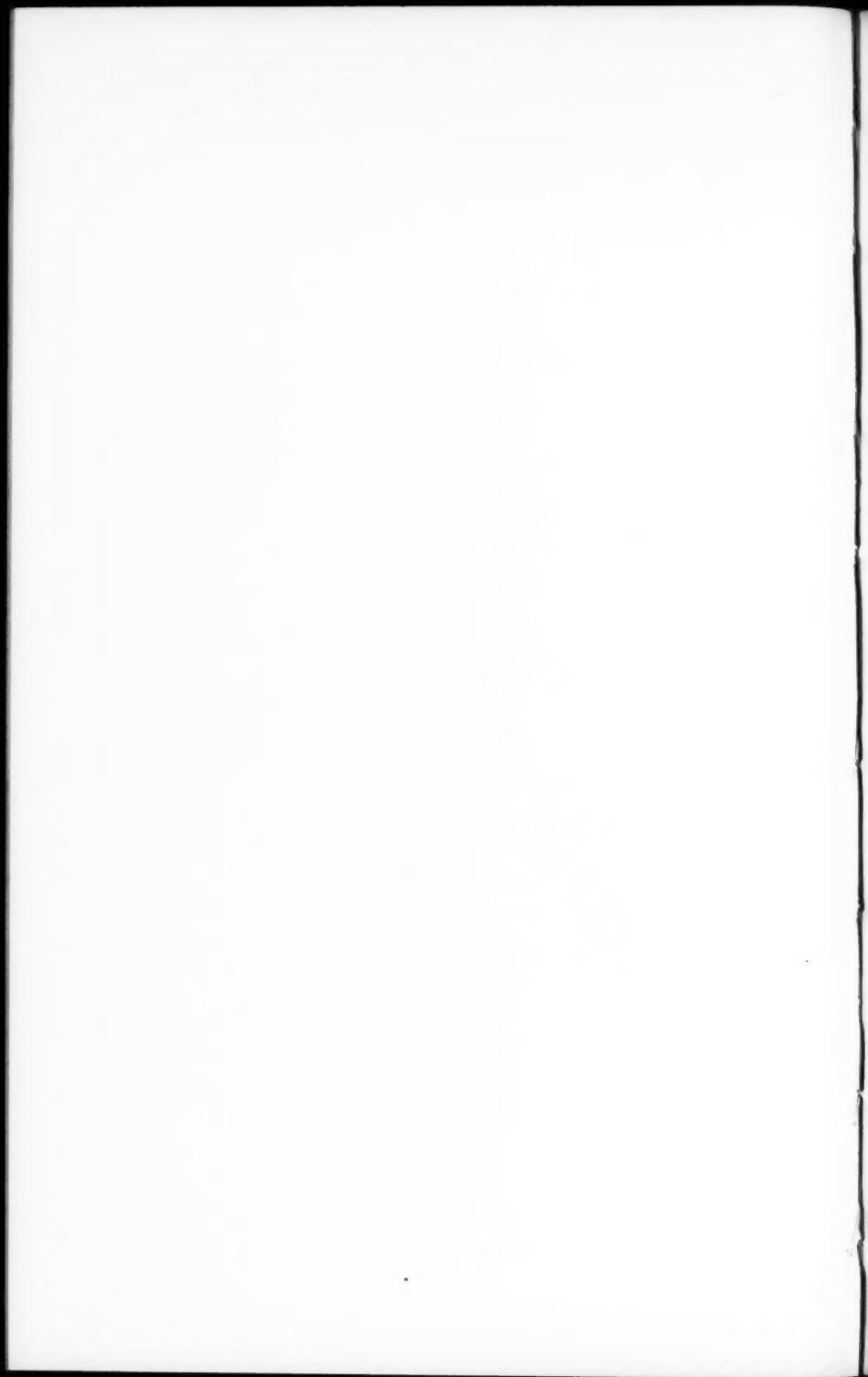
A study of the nuclear phenomenon of the conidial stages during spore formation and germination would undoubtedly throw much light upon the whole subject.

The important feature of parallelism as herein outlined is the assistance given the mycologist and plant pathologist to anticipate with some accuracy the probable relationship between conidial and ascosporic stages.

Thanks are due Professors R. A. Harper and F. D. Kern for



SPORE-FORMS IN THE ASCOMYCETES



helpful criticism during the preparation of the manuscript for publication.

PENNSYLVANIA STATE COLLEGE,
STATE COLLEGE, PA.

EXPLANATION OF PLATE CLII

All figures except figure 2 are magnified about 100 times

Fig. 1. *Ophionectria*. Adapted from Florida Bulletin 119. *A*. Ascospores.
B. Conidium.

Fig. 2. *Endothia parasitica*. Redrawn from Cornell Bulletin 347. *A*. Ascospore germinating. *C*. Conidium germinating.

Fig. 3. *Curcurbitaria*. *A*. Ascospores. *C*. Conidia.

Fig. 4. *Pleospora*. *A*. Ascospore. *C*. Conidium.

Fig. 5. *Coccomyces*. Redrawn from Higgins. *A*. Ascospores. *C*. Conidia.

Fig. 6. *Venturia*. *A*. Ascospores. *C*. Conidia.

Fig. 7. *Gibberella*. *A*. Ascospore. *C*. Conidia.

THE TAXONOMIC VALUE OF PORE CHAR- ACTERS IN THE GRASS AND SEDGE RUSTS¹

J. C. ARTHUR AND F. D. FROMME

It is only in recent years that the germ-pores of the urediniospores of the rusts have been the objects of critical study by the mycologist. This study has been prompted by the desire to find additional morphological characters of sufficient constancy and clearness for taxonomic purposes.

The first consistent use of urediniospore-pore characters in the description of rust species was made by the senior author of this paper in the second number of the North American Uredineae, issued in 1898 and printed in the Bulletin of the University of Iowa. They had occasionally been incorporated in descriptions prior to this but had not been used with any constancy. The prevailing tendency had been to regard all of the urediniosporic characters as of slight taxonomic value and to place the greater dependency on characters of the teliospores. The recent authors of systematic works on the rusts who have used urediniospore-pores most consistently are Fischer, Holway, Bubak and Grove. None of these authors, however, have incorporated these pore characters in their keys as has been done in the rust part of the North American Flora, the first number of which was issued in 1907.

In no groups of the rusts has the taxonomist's need of sharply distinctive morphological characters been more imperative than in those which have their uredinal and telial stages on grass and sedge hosts. These are included under two genera, *Nigredo* (*Uromyces* in part) and *Dicaeoma* (*Puccinia* in part); the former with one-celled and the latter with two-celled teliospores. There is a growing belief, which has been strengthened by the study of the urediniospore-pores, that there is no essential difference between the two genera and that the presence of more than one cell

¹ Read before the Botanists of the Central States, at the St. Louis meeting, October 17, 1914.

in the teliospore is a racial feature rather than an acceptable morphological basis of separation. When both one- and two-celled teliospores occur together the generic assignment is arbitrary, it being understood that the two-celled spores are to be given preference, even if comparatively few, or if quite absent in part of the sori or on some hosts. The species may still be maintained in two genera for convenience and in conformity with usage. The determination of the species, however generically disposed, on teliosporic characters alone is often a difficult task and sometimes an impossibility, on account of the great similarity of the forms. It has become necessary, therefore, to utilize such other characters as are available and especially those of the urediniospores.

Urediniospores can usually be found in collections of grass and sedge rusts even though no uredinial sori are present. A scraped mount made from a sorus of teliospores will usually contain a few of the other spores even if the collection be made at a season when uredinial production has apparently ceased. There are, however, three species of grass rusts, *Puccinia leptospora*, *P. Campulosi* and *P. paradoxica*, in none of which have urediniospores been observed. These are rare species represented by single collections only. Teliospores, on the other hand, are by no means an omnipresent spore form of the grass and sedge rusts. They are seldom present in uredinial sori at the optimum growth period of the host, and in many species they are almost entirely wanting throughout the whole season, as in the common rust of blue-grass, *Puccinia epiphylla*, which produces teliospores in North America in alpine or boreal regions only. The urediniospore is, as a rule, the most abundant spore form and its characters are sufficiently constant and distinctive to make it of great value for taxonomic purposes.

The most useful urediniosporic characters are: the form and size of the spore, the color and thickness of the spore wall, its surface sculpturing, and the number and distribution of the germ-pores. Among these the pore characters are perhaps the most valuable. The pores are usually visible in a water mount but it is often better to use a clarifying or staining agent to bring them out distinctly. A small drop of lactic acid mixed with the water in which the spores are mounted, especially if heated to

the boiling point, is very effective, as is also the application of a solution of chloral hydrate and iodine. The latter is particularly serviceable when the spores are fresh and still retain their colored contents. These methods fail, however, in a few species having urediniospores with colorless or thick gelatinized walls. There are five of these species: three, *Puccinia versicolor*, *P. Boutelouae*, and *P. triarticulata*, in which the pores are evidently scattered but the exact number cannot be made out, and two species, *P. Seymouriana* and *P. Melicae*, in which neither the pore number nor distribution is known.

According to our present knowledge there are 145 species of rusts on grass and sedge hosts in North America having available pore characters; 105 species on grasses and 40 on sedges. The following account of urediniospore-pores is based upon this group of species, which includes those with both one- and two-celled teliospores.

In the grass rusts the urediniospore-pores vary in number with the different species from 2 to 12. In species where the pores are restricted to the equatorial zone the most common number is 3 or 4, and where the pores are scattered, 6 or 8.

In the sedge rusts the range of variation, 1 to 5, is much smaller, five pores being the largest number known. The two-pored condition is most common and the one-pored condition, found in two species only, is rare.

The extent of variation in number of pores in a single species is usually small. A variation of four, as from 8 to 12, is the extreme. Many species have a variation of two, as from 2 to 4, 4 to 6, etc., or of one, as from 2 to 3 or 3 to 4, and in many the pore number is fixed.

The real significance of the pore number from the physiological standpoint is not known and no theory to account for the presence or importance of more than one pore in each spore has been put forth. The pore number and distribution are no doubt associated in some way with the development of the species and possibly bear a physiological relation to the host. Their absolute hereditary constancy has never been proven. An apparent physiological modification in the pore number and distribution is known in *Puccinia*

vexans, a common rust of the prairies on species of *Bouteloua*. In addition to the normal thin-walled urediniospores this species produces a resting or amphisporic form of urediniospores. These amphispores have a thick, dark-colored wall and are easily mistaken for teliospores of *Uromyces*. They show their urediniosporic nature, however, by the production of a germ-tube instead of a promycelium, and by their ability to reinfect the same host. The normal urediniospores of this species have eight scattered pores, while the amphispores have four equatorial pores (Fig. 1, *b* and *c*). An explanation of the difference in number and position of the pores in the active and resting urediniospores should give a valuable insight into the evolution of this stage of the rusts.

It is sometimes more difficult to ascertain the disposition of the pores than their number. This is especially true in a globoid spore, as it is hard to be certain that it is properly orientated, but an ellipsoid or oblong spore will naturally lie upon the proper surface for convenient examination. Three general types of distribution are recognized: scattered, equatorial, extraequatorial.

The term scattered pores does not imply that the pores are without a definite arrangement. They are practically equidistant from each other over the cell surface in the typical scattered-pore condition (Fig. 1, *a*, *b* and *d*).

If the pores are equatorial, they more or less approximate the equator of the spore and are placed at about equal distances apart (Fig. 1, *e*, *f*, *g*, and *h*).

The extraequatorial group may be conveniently subdivided into pores superequatorial, and pores subequatorial. Like the equatorial-pored condition these are zonal arrangements when more than one pore is present. The zone may be slightly above or below the equator (Fig. 1, *j*), considerably above, near the apex (Fig. 1, *i*), or considerably below, near the hilum (Fig. 1, *k* and *l*). Two pores is the constant number for all of the extraequatorial-pored species except those with pores near the hilum. One species, a grass form, *Puc. Sporoboli*, has three pores arranged in a zone around the hilum, while two species, both sedge forms on species of *Carex*, each have a single pore near the hilum.

The scattered- and equatorial-pored conditions are present in

about equal numbers in the rusts under consideration. There are at present known 63 species with scattered pores and 67 with equatorial pores. Fifteen species have extraequatorial pores, eleven

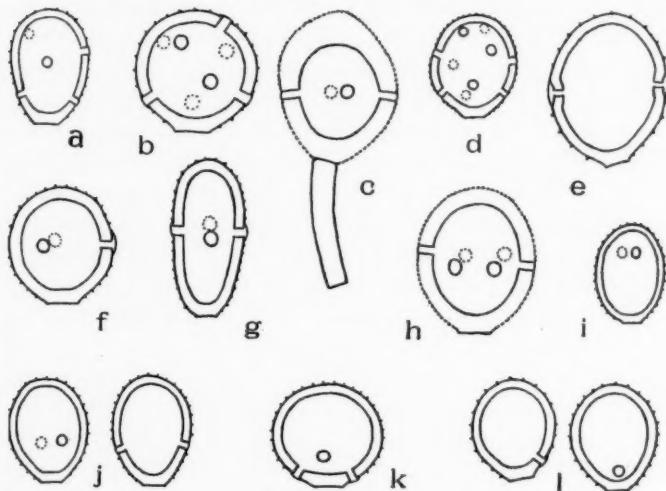


Fig. 1, *a*, *b*, *d-l*, urediniospores and *c*, amphispore, all from North American collections: *a*, *Uromyces Poae*, 5 scattered pores; *b*, *c*, *Puccinia vexans*, 8 scattered pores and 4 equatorial pores; *d*, *P. epiphylla*, 10 scattered pores; *e*, *P. Cenchi*, 2 equatorial pores; *f*, *P. Urticae*, 3 equatorial pores; *g*, *P. foculiformis*, 4 equatorial pores; *h*, *P. eslavensis*, 6 equatorial pores; *i*, *P. Caricis-Asteris*, 2 superequatorial pores; *j*, *P. Caricis-Strictae*, 2 subequatorial pores; *k*, *P. Sporoboli*, 3 basal pores; *l*, *Uromyces uniporus*, 1 basal pore. All spores magnified 625 diameters.

of which are super- and four subequatorial. Expressed in percentage, the different divisions stand as follows: pores equatorial 46.2 per cent.; pores scattered 43.5 per cent.; pores superequatorial 7.6 per cent.; pores subequatorial 2.7 per cent.

None of the grass rusts has superequatorial pores and but a single species has subequatorial pores. All of the remaining species, therefore, in which the pores are known, belong to the scattered- or equatorial-pored groups, 63 species in the former group and 42 in the later.

Among the sedge rusts the scattered-pored condition is very uncommon, being found in but a single species, *i. e.*, *Puc. karelica*.

The equatorial-pored condition is most common here and is present in 25 species, while eleven species have superequatorial pores and three have subequatorial pores.

The practical importance of a thorough understanding of the pore characters of the urediniospores of the grass and sedge rusts, apart from the possible clues of relationship and phylogeny that may be derived from it, lies in the application of the knowledge to the identification of incomplete material. In many cases collections that are of considerable importance in mapping the range of a species or in determining its validity are represented by a few fragments of leaves that the taxonomist is unable to place and the rust material may be scanty and wholly or chiefly in the uredinial stage. The too common practice of gathering a few infected leaves without inflorescence or fruit supplemented by the failure to properly label the collection in the field leads to many errors in the naming of hosts which the uredinologist is sometimes able to rectify through the proper identification of the parasite. If a rust in question on an unidentified grass-like fragment of leaf has scattered urediniospore-pores or a greater number than five the assumption is that the host is a grass since but a single sedge rust has scattered pores and none has more than five. If the pores are superequatorial, the host is most certainly a sedge.

With the few broad bases of separation afforded by the pore characters and with the other supplementary characters of the urediniospores, it is often possible to determine the species of rust from urediniosporic material alone, which is a far cry from the situation prevailing not many years ago when grass and sedge rusts, especially the latter, were considered the most difficult of all the rusts to determine, and utterly hopeless when only urediniospores were present.

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A PARASITIC SPECIES OF CLAUDOPUS

HARRY MORTON FITZPATRICK

(WITH PLATE 153, AND 1 TEXT FIGURE)

Several of the *Agaricaceae* have been described as parasitic on others of the same group. Of these may be mentioned *Volvaria Loveiana* on *Clitocybe nebularis*,¹ *Stropharia coprinophila* on *Coprinus atramentarius*,² and the species of the genus *Nyctalis*. No instance of a species of the *Agaricaceae* parasitic on one of the *Polyporaceae* appears, however, to have been cited. On August 2, 1914, the writer discovered such a case in Six Mile Gorge, near Ithaca, N. Y. *Polyporus perennis*³ occurs in this locality in unusual abundance and a few fruit bodies of this fungus were found parasitized a member of the genus *Claudopus*. Study has proved this to be a hitherto undescribed species.

The fruit bodies of the parasite occur in considerable numbers about the mouths of the tubes and along the stipe of the *Polyporus*. They are minute, the expanded pilei in no case exceeding 4 mm. in diameter, while the developmental stages or "buttons" are almost microscopic. The lateral stipe and the salmon-colored gills suggest at once the genus *Claudopus*.

The parasitized host plants, if examined superficially, give little evidence of the presence of the parasite. They exhibit the normal appearance of healthy plants, showing neither hypertrophy nor dwarfing, and viewed from above can in no way be distinguished from the uninfected sporophores. An examination with the hand lens reveals the fact that certain of the tubes of the *Polyporus* in the immediate vicinity of the fruit bodies of the parasite are partially filled with the grayish mycelium of the *Claudopus*. There is no other external evidence of a diseased

¹Berkeley, J. M. Outlines of British Fungology, pl. 7, f. 2. 1860.

²Atkinson, G. F. A mushroom parasitic on another mushroom. The Plant World 10: 121-130. f. 22-24. 1907.

³*Polyporus perennis* Fr. = *Coltricia perennis* (L.) Murrill. North American Flora 9: 92. 1908.

condition, and the sporophores of the *Polyporus* produce their hymenium and spores in the normal manner. Thin sections made through the point of attachment of the stipe of the parasite to the host disclose no marked derangement of the elements of the latter. It is possible to trace to some extent the course of the hyaline hyphae of the *Claudopus* among the deeper-colored threads making up the sporophore of the *Polyporus*. Some of these are found ramifying the trama of the host to a considerable depth. It is possible that they extend through its stipe to the soil. The presence of fruit bodies of the parasite on the stipe furnishes some indication of this.

The mycelium of the parasite is relatively small in amount, and the hyphae of the two fungi lie in close contact and run approximately parallel. Careful search fails to reveal any organs of the nature of haustoria, and dissolution of the host hyphae by enzymes excreted by the parasite appears not to take place. If any such process occurs, the disintegration of the host is insufficient in amount to be evident in thin, free-hand sections.

The method by which natural infection occurs was not determined. Fruit bodies of the *Claudopus* leading a saprophytic existence on neighboring twigs or soil could not be found. It is not impossible, however, that these were produced earlier and had already disappeared. Local infection of the sporophores of the *Polyporus* might result either from spores produced on such saprophytic fruit bodies or from hibernated spores produced the preceding year on parasitic fruit bodies. It seems more probable, however, that the vegetative mycelium of the *Claudopus* spreads in the soil and travels upward among the hyphae of the *Polyporus* during the development of its sporophore. It may thus retain organic connection with the food material in the soil and be partially or wholly independent of the *Polyporus* in its food relationships.

The upper figure in the accompanying plate illustrates well the fruit bodies of the two fungi. A compound structure resulting from the fusion of the pilei of three sporophores of the host plant is shown. The blur at the center of the photograph results from the failure of the stipe of the sporophore to fall into focus. The tendency of the sporophores of *Polyporus perennis* to fuse at the

margins with neighboring fruit bodies is more or less characteristic of the species. It was evident in many of the plants collected, has been described before, and is not to be regarded as due to the presence of the parasite. Nearly one hundred fruit bodies of the *Claudopus*, the majority of them in the "button" stage, may be counted on the single sporophore pictured. They are shown enlarged to approximately two diameters. The lower figure in the plate illustrates the parasite in somewhat more detail, the enlargement here being nearly four diameters.

The fungus must be regarded as a member of the genus *Claudopus*. The stipe is definitely lateral. The spores, salmon-colored in mass, when viewed under the microscope exhibit a distinct pink tint. However, no previously described species of the genus possesses the characters of the fungus on *Polyporus perennis*. No described species of *Pleurotus* or *Crepidotus* resembles it even remotely. The pileus is white, the lamellae are salmon-colored in even the young fruit bodies, and the spores are definitely angular (see text figure 1). Few species of the genus have been described as having angular spores. Only one of these, *Claudopus depluens* Batsch, has a white pileus, and it is described as being sometimes tinged with pink or gray. The minimum measur-

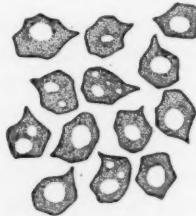
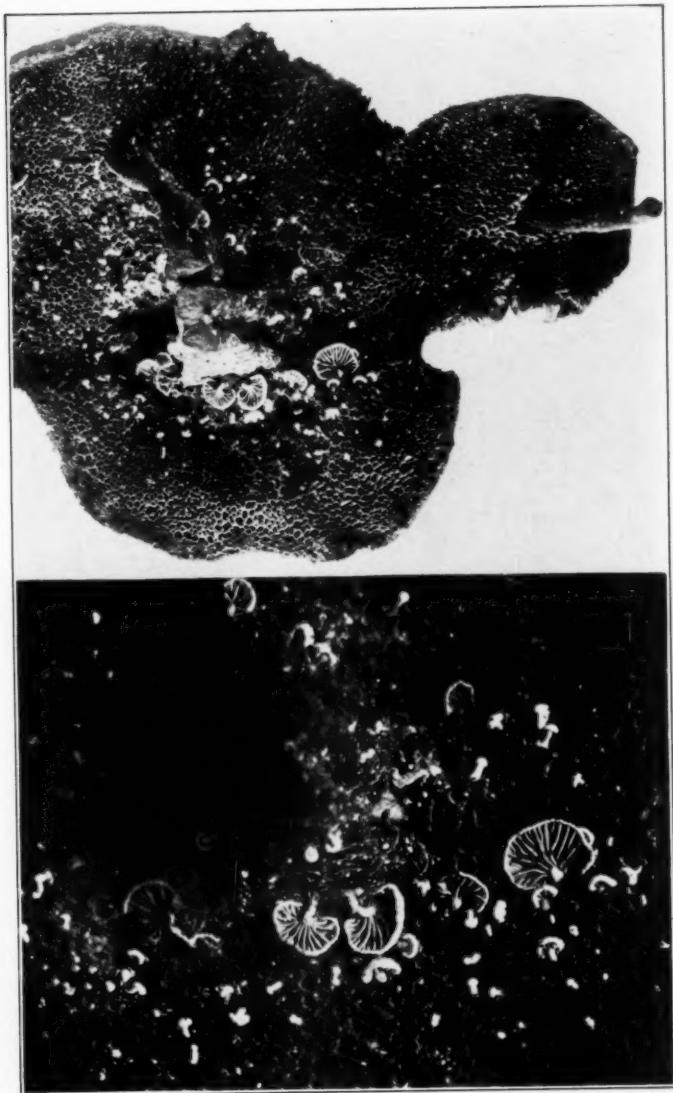
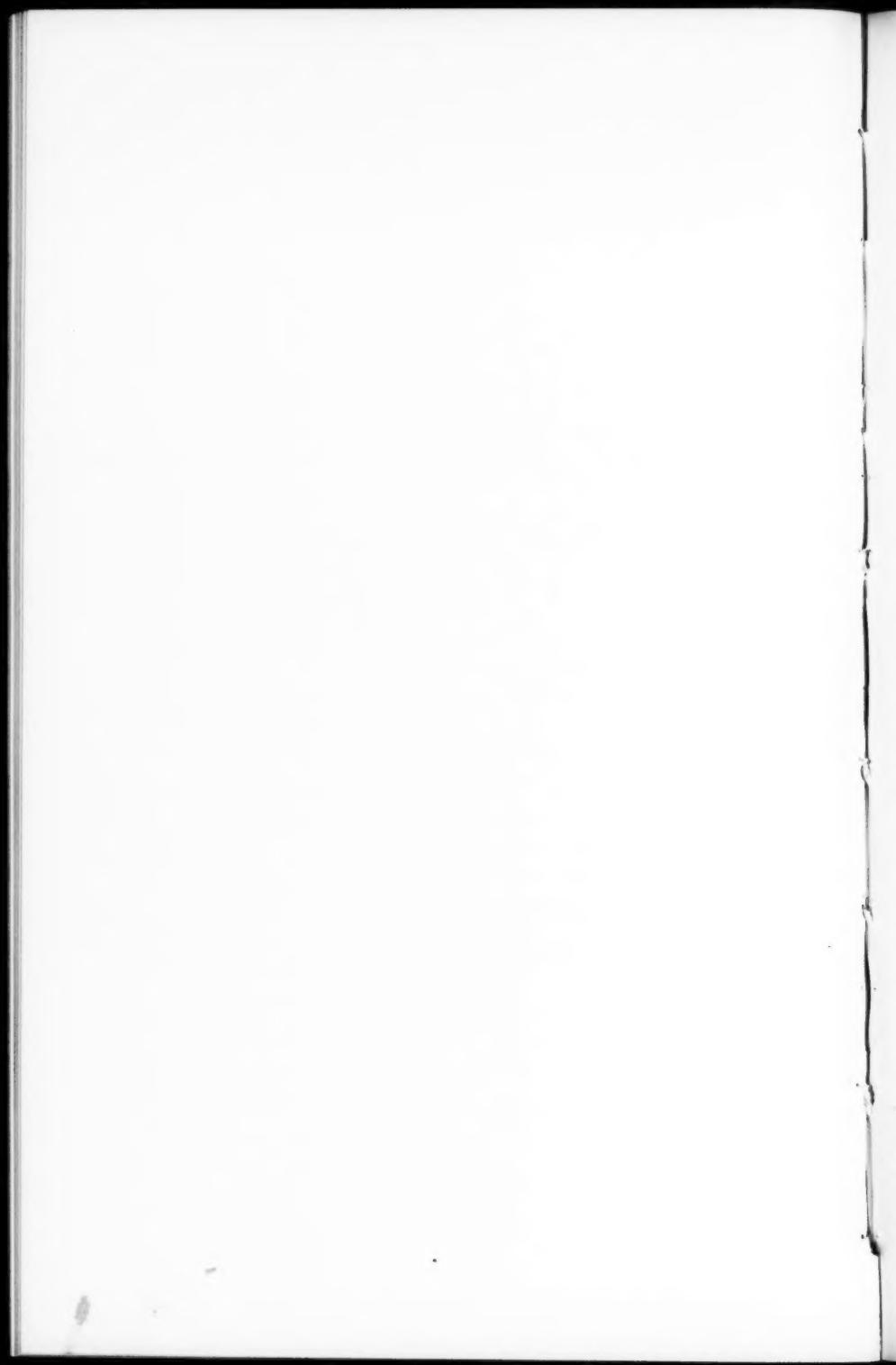


FIG. 1. Spores of *Claudopus subdepluens* Fitzpatrick.

ment (one-half inch) given as the diameter of the pileus of *C. depluens* is three times greater than the maximum of the species under consideration, while average pilei of *C. depluens* are much larger. The fruit bodies of *C. depluens* occur on the ground or on decaying wood, and arise from saprophytic mycelium. The lamellae are at first white, later becoming salmon-colored. The species has been collected in New York and was described by



CLAUDOPUS SUBDEPLUENS FITZPATRICK



Peck.⁴ The spores of the two species are approximately the same size, and are both typically uniguttulate. The fungus on *Polyporus perennis* is evidently closely related to *C. depluens*. It cannot, however, if the differences enumerated are taken into consideration, be regarded as identical with it, and the following name is proposed:

***Claudopus subdepluens* sp. nov.**

Pileo e convexo expanso, minuto, 1-4 mm. maximam diam., albo, minute tomentoso, margine sulcato; lamellis ex primo salmoniis, distantibus, adnatis, acie integerrima; stipite albo, laterali, flexuoso, adusque 2 mm. longitudinem, crassitudine minore quam 0.5 mm.; basidiis 4 sterigmatibus praeditis, clavatis; sporis angulosis, 1-guttulatis (raro 2-plus-guttulatis), parum atqui definite roseis, $7-12 \times 6-8 \mu$.

Hab. parasiticus in *Polyporo perenne*, Six Mile Gorge, Ithaca, N. Y. Amer. bor.

DEPARTMENT OF PLANT PATHOLOGY,
CORNELL UNIVERSITY,
ITHACA, N. Y.

⁴ Peck, Chas. New York species of *Pleurotus*, *Claudopus*, and *Crepidotus*. Ann. Rep. N. Y. State Mus. 39: 68. 1887.

NEW SPECIES OF COLLETOTRICHUM AND PHOMA

P. J. O'GARA

A NEW SPECIES OF COLLETOTRICHUM ON CLOVER

During the course of my investigations in the Salt Lake Valley, I have found many clover fields in which the stems and petioles of red clover (*Trifolium pratense* L.) and alsike clover (*Trifolium hybridum* L.) were infected with a *Colletotrichum* which does not agree in its characteristics with *Colletotrichum Trifolii* Bain. However, in many respects the characters of the disease are similar to those of *Colletotrichum Trifolii* as described by Bain and Essary.¹

The clover plants seem to be most frequently attacked at or near the ground, although it has been noted that the attack may also occur just beneath a cluster of blossoms. As a rule, one's attention is called to the sudden dying of a cluster of blossoms. The petioles and stipules are also attacked.

Specimens of diseased plants were sent to Mrs. F. W. Patterson, mycologist of the U. S. Department of Agriculture, at Washington, D. C., and also to Professor S. M. Bain of the University of Tennessee. Reports from both sources indicate that the disease of red clover and alsike clover as found in the Salt Lake Valley is not caused by *Colletotrichum Trifolii* but by a heretofore undescribed species. A more complete statement of the characteristics of the disease will be made at a later date. The description follows:

***Colletotrichum destructivum* sp. nov.**

Maculis indeterminatis brunneis; *acerulis* minutis 25-70 μ diam., sparsis v. gregariis, erumpentibus, elevatis; *mycelio* hyalino, granuloso; *basidiis* fasciculatis, hyalinis, cylindraceis v. fusoides, conidiis prope aequalibus; *conidiis* hyalinis, granulosis, 1-4 guttulatis, rectis v. leniter curvulis, utrinque rotundatis 3.5-

¹ S. M. Bain and S. H. Essary. A new anthracnose of alfalfa and red clover. *Jour. Myc.* 12: 192. 1906.

$5 \times 14-22 \mu$; *setulis* inter condidia orientibus, paucis v. numerosis, fuligeneis v. atro-brunneis, subrectis v. curvulis v. flexuosis, saepe nodulosis, continuis v. obscure 1-septatis, subacutis v. rotundatis, sursum angustioribus, basi $4.5-7 \mu$ crassis, $38-205 \mu$ longis.

Hab. in foliis, petiolis caulibusque vivis et languidis Trifolii pratensis, Utah, Amer. bor.

A NEW SPECIES OF COLLETOTRICHUM ON POTATO

A new species of *Colletotrichum* which confines its attacks mostly to the underground stems of the potato has been found in many potato fields in the Salt Lake Valley, Utah. Rarely is this new species found on the stems above the surface of the ground. Sometimes definite, dark-brown or black cankers are produced resembling to some extent those caused by *Rhizoctonia*, but more often the entire underground stem is involved. The mycelium invades the cortex beneath the epidermis and is at first hyaline and few-septate. Later, the mycelium becomes brown and many-celled, and forms sclerotia-like bodies just beneath the epidermis from which arise the setae and conidiophores. When the stems die, the epidermis readily comes off, exposing the dark-brown or black sclerotia-like bodies. The fungus has been cultivated in the laboratory for some time, and reproduces characteristically. It is related to *Vermicularia*.

Colletotrichum solanicolum sp. nov.

Maculis plus minusve indeterminatis atro-brunneis vel nigris, plerumque in caulibus subterraneis, saepe totum partem caulin subteranii occupantibus; *acervulis* numerosis, irregulariter sparsis vel subgregariis, primo epidermide tectis, demum erumpentibus; *mycelio* in cellulis corticis primo hyalino et parce septato, deinde brunneo, pluriseptato, sclerotioideo, conidia setasque gerente; *setis* fasciculatis, numerosis, atro-brunneis, ad apicem saepe pallidioribus, rectis, vel leniter curvulatis vel flexuosis, apice obtusis vel acutis, 1-3 septatis, $90-260 \mu$ longis, cellula inferiore leniter inflatis, $6-7 \mu$ crassis; *conidiophoris* inter setulis orientibus, subhyalinis, granulosis, brevibus, $2-8 \mu$ longis; *conidiis* continuis, $3.5-5 \times 17-22 \mu$, rectis vel leniter curvulatis, apice rotundatis, ad basim leniter attenuatis, hyalinis, granulosis, saepe 1-3 guttulatis, maturescentibus vacuolum leniter refringens medio continentibus.

Hab. in caulibus subterraneis vivis et emortuis *Solanum tuberosi*, Salt Lake Valley, Utah, Amer. bor.

A NEW SPECIES OF COLLETOTRICHUM ON ASCLEPIAS

My attention was called to an interesting anthracnose of *Asclepias speciosa* by Mr. W. W. Jones, botanist in the laboratory of plant pathology, department of agricultural investigations, American Smelting and Refining Company. Upon careful study of the disease, it was found that a new species of *Colletotrichum*, more or less intermediate between *Gloeosporium* and *Colletotrichum*, proved to be the causative agent. It is interesting to note that this new species of *Colletotrichum* produces very few setae; very often they are entirely wanting. The fungus attacks both the foliage and the stems, producing characteristic irregular spots on the foliage and most often a complete girdling of the stems near the base. The spots on the stems when not confluent are more or less elliptical. The conidial masses on both foliage and stems are distinctly salmon-colored in fresh specimens. Diseased plants are easily noted by the premature yellowing of the foliage.

A more complete description will be presented later when the cultural work has been completed. The description of the species is as follows:

***Colletotrichum salmonicolor* sp. nov.**

Maculis in caulibus et foliis, brunneis, atro-brunneo-marginatis. *Maculis* in foliis amphigenis, irregularibus, leniter depresso, 2-6 mil. diam., saepe confluentibus. *Maculis* in caulibus, lenticulatis, saepe confluentibus, initio leniter depresso, deinde elevatis, 2-7 mil. long. *Acervulis* amphigenis, sed in hypophyllo copiosoribus, minutis, numerosis, irregularibus, elevatis, dense aggregatis interdum confluentibus, initio epidermide velatis, dein erumpentibus, massa conidiorum salmonicoloratis erumpente; *conidiis* subhyalinis, granulosis, 2-4 guttulatis, irregularibus, rectis vel levissime curvatis, saepe ad basim leviter attenuatis et summo rotundatis, 5-6 \times 17.5-35 μ ; *basidiis* hyalinis, granulosis, conidio subaequilongis; *mycelio* parce vel non septato; *setulis* erectis, sparsis, paucis, saepe nullis, superne acutis 1.5 μ crassis, inferne 9 μ crassis, 2-3 septatis et 75-105 μ longis, rectis vel leniter curvulatis, saepe nodulosis, atro-fuligineis vel brunneis, cellula inferiori subhyalina.

Hab. in caulibus et foliis vivis et languescentibus *Asclepiadis speciosae*, Salt Lake Valley, Utah, Amer. bor.

A NEW SPECIES OF PHOMA ON ASCLEPIAS

Upon examining some mycological collections made by W. W. Jones of this department during the past season in the Salt Lake Valley, Utah, I found an interesting *Phoma* on the stems and foliage of *Asclepias speciosa* Torr. The examination of many specimens showed that in every instance it was associated with *Cercospora clavata* (Ger.) Peck. The leaf and stem spots always showed the presence of both the *Phoma* and *Cercospora*. In some cases definite areas of the spots were covered by both species, but often the pycnidia of the *Phoma* and the acervuli of the *Cercospora* are intermingled. Where definite areas of the spots are covered by the two species, it is easy to recognize one from the other by noting the lighter-colored brown areas of the *Cercospora* as contrasted with the dark-brown or black-colored areas occupied by the *Phoma*. Carefully prepared microtome sections show the intermingling of the mycelium of both species. In the *Phoma* leaf-spots, practically the entire structure between the upper and lower epidermis is destroyed, and the space occupied by the light-brown mycelium. Pycnidia are often distinctly beaked. The description of this species is as follows:

Phoma rostrata sp. nov.

Maculis in caulis lenticulatis vel elongatis; in foliis amphigenis irregularibus, nervulis limitatis, atro-brunneis vel nigris; *peritheciis* sparsis vel dense gregariis, brunneis vel atro-brunneis, semi-immersis, globosis, prominulis vel rostratis, $56-95 \mu$ diam.; *mycelio* in cellulis hospitis brunneo, ramoso, pluriseptato, hyphis circa 3μ diam.; *sporulis* $1.4-2.3 \times 4-6 \mu$, eguttulatis, oblongis, utrinque rotundatis, plerumque leniter curvulatis; basidiis non vivis.

Hab. in foliis et caulis vivis et languidis *Asclepiadis speciosae*, cum *Cercospora clavata* in eisdem maculis sociata, Salt Lake Valley, Utah, Amer. bor.

LABORATORY OF PLANT PATHOLOGY,
DEPARTMENT OF AGRICULTURAL INVESTIGATIONS,
AMERICAN SMCETING & REFINING COMPANY,
SALT LAKE CITY, UTAH.

LIND'S WORK ON THE ROSTRUP HERBARIUM

LARS ROMELL

I beg to draw the attention of mycologists to an excellent work on Danish fungi as represented in the herbarium of E. Rostrup, revised by J. Lind. It is a big volume of about 650 pages in large 8vo, printed at the expense of the Carlsberg Fund.

The author, whose thoroughness and eminent ability we know from his previous publications, has in this monumental work proved himself a mycologist of high rank.

A general idea of the aim and outline of the work may be obtained from the following statement from Lind's introduction: Shortly after the death of Professor E. Rostrup, Ph.D., which occurred on January 16, 1907, I was intrusted with the honorable task of preparing a list of all the species of Danish fungi found in his herbarium. This herbarium was acquired by the University of Copenhagen and has been included in the Botanical Museum of the University. On account of the copiousness of this herbarium, the list will comprise all species of fungi which have hitherto been found in Denmark belonging to the groups of fungi with which Rostrup was mostly occupied. However, in preparing the list, I have also endeavored to point out what an uncommonly diligent man and accurate investigator Rostrup has been. It was my intention in this way to establish a memorial in honor of E. Rostrup as a mycologist and phytopathologist which shall bear witness in foreign countries to the modest and laborious man whose importance as a scientist was never fully understood because he mostly wrote in Danish.

The subject matter of the first part of the book (pages 1-47) may be suggested from the following heads: "The collection of Danish fungi left by the late Professor E. Rostrup," "Danish mycologists previous to Rostrup," "Phytopathology in Denmark before Rostrup," "The assistants of E. Rostrup in the mycological investigation of Denmark," "Foreigners who have taken

part in the mycological investigation of Denmark," "The plan of the work."

This part gives a most valuable exposition of the history of the mycological exploration of Denmark from the middle of the seventeenth century up to the present time. The list of contributors to this exploration is quite large, and biological notes of interest accompany each name, while the most important ones are treated in detail and the following are illustrated by portraits, viz.: E. Røstrup, Th. Holmskjold, G. C. E. von Oeder, O. F. Müller, M. Vahl, C. F. Schumacher, A. S. Øersted, J. C. Fabricius, E. C. Hansen, J. L. Jensen, M. L. Mortensen, P. Nielsen, and C. J. Johanson.

The second or main part of the work (pages 49-550) gives a systematic exposition of all known Danish species (3,324 in number) of Phycomycetes, Ascomycetes, Basidiomycetes, and Fungi Imperfecti. This is, however, no mere list of names. It is a critical and thorough revision of these great groups of fungi with diagnoses or interesting comments accompanying a large number of the species and with many excellent illustrations. Some of the species are here published for the first time.

As to nomenclature, the author says: "I have followed the rules for nomenclature adopted at the International Congress in Brussels, in May, 1910, viz.: that Fries' 'Systema Mycologicum' should be the starting point for the nomenclature of the fungi, except for the Uredinales, Ustilaginales, and Gasteromycetes, which date from Persoon's 'Synopsis.'"

The third part (pages from 555 to the end) contains a "List of literature," "Index of Danish names," and "Index universalis."

The work is written in English and can be used with advantage all over the world. I cannot abstain from strongly recommending it to every mycologist. The price is 20 danish crowns (about 5½ dollars).

STOCKHOLM,
SWEDEN.

A NEW BOLETE FROM CALIFORNIA

WILLIAM A. MURRILL

In a collection of boletes recently received from the department of botany of the University of California, the following is not only new but also of special interest because of its rather unusual characters:

Rostkovites californicus sp. nov.

Pileus thick, convex to plane, solitary, 6-9 cm. broad; surface smooth, conspicuously subtomentose, brown, margin concolorous, entire, rather thick; context thick, fleshy, flavous, unchanging, taste mild; tubes adnate, plane or slightly convex in mass, 4-6 mm. long, yellow, exuding drops which blacken with age, mouths large, angular; spores oblong-ellipsoid, smooth, yellowish-brown, $7-8 \times 3.5-4 \mu$; stipe subequal or bulbous, smooth, yellow, with black dots, unchanging, solid, yellow within, unchanging, 3-6 cm. long, 1.5-2 cm. thick.

Type collected on the ground in pine woods in Grass Valley, California, November 12, 1914, H. S. Yates & F. H. Bolster 251 (herb. N. Y. Bot. Gard.). Excellent field notes accompany the specimens. The species is strikingly different from other members of the genus in having a conspicuously subtomentose surface resembling that of *Ceriomyces communis*.

NOTES, NEWS AND REVIEWS

Professor Bruce Fink held a research scholarship at the Garden in December, 1914, and delivered a special address on lichen taxonomy before the Torrey Botanical Club.

Professor L. H. Pennington completed his studies of the temperate species of *Marasmius* at the Garden during the latter part of December.

Professor W. C. Coker has sent in a valuable collection of gill-fungi from Chapel Hill, North Carolina, containing a splendid representation of several difficult species.

Dr. Frederick D. Heald has been appointed professor of plant pathology and pathologist at the State College and Experiment Station, Pullman, Washington.

The American Journal of Botany for July, 1914, contains an article on the origin and development of the lamellae in *Coprinus micaceus*, by Dr. Michael Levine, which forms a valuable addition to the scanty literature of the morphology of the higher fungi.

In the Report of the Connecticut Agricultural Experiment Station for 1913, Dr. G. P. Clinton discusses rather fully the so-called chestnut blight poisoning and decides that the chestnuts eaten by the persons affected could have had no distinctive poisonous properties, but may have been imperfectly matured owing to the trees being attacked by the blight.

The life history and physiology of *Cylindrosporium* on stone fruits is ably treated in an article by B. B. Higgins in the *American Journal of Botany* for April, 1914. Dr. Higgins describes two species as new, *Cocomyces prunophorae* and *C. lutescens*, in addition to *C. hiemalis* previously described by him in *Science*

Mr. F. J. Veihmeyer, in Bulletin 127 of the U. S. Department of Agriculture, discusses the Mycogone disease of mushrooms and its control. This disease has been known in Europe for at least three generations and has been very destructive to mushroom beds. It was reported in America only a few years ago and now threatens the mushroom industry in certain localities. Methods of prevention and control are discussed at length in this bulletin.

Plants of *Oenothera Tracyi* grown at the New York Botanical Garden during the past two years have had their leaves almost completely covered with mildew (*Erysiphe*), which gives them a decided grayish-white color. Plants of *O. grandiflora*, however, growing by the side of *O. Tracyi* seem to be completely immune from the attacks of this fungus and their foliage has remained bright-green throughout.

The *Strumella* disease of oak and chestnut trees is described and fully illustrated by F. D. Heald and R. A. Studhalter in Bulletin 10 of the Pennsylvania Department of Forestry. This disease very much resembles the chestnut canker and attacks not only chestnut but also various species of oak in the northeastern United States. The fungus, *Strumella coryneoides* Sacc. & Wint., is an old species, but has not previously been considered parasitic in habit. The investigations in this bulletin have been confined to the state of Pennsylvania.

A very interesting list of wood-destroying fungi which grow on both deciduous and coniferous trees, by James R. Weir, appears in the August number of *Phytopathology*. These observations show that too much dependence must not be placed on the host as an aid in determining certain wood-loving species. One of the most striking instances recorded by the author is that of *Grifola Berkeleyi* attacking the roots of the larch in the Kankakee National Forest of Idaho. This handsome species is known in the East only on oak.

The Transactions of the Wisconsin Academy of Sciences, Arts, and Letters, Volume 17, Part 2, issued in October, 1914, contains several very important mycological contributions. Bernard O. Dodge contributes a list of fungi, chiefly saprophytes, from the region of Kewaunee County, Wisconsin, including 400 species from Kewaunee County and 40 additional species from Juneau and Dane Counties listed because of their special interest. About 90 species of discomycetes found in this same region were also listed by Dr. Dodge in another paper in the same publication. Both of Dr. Dodge's papers contain locality and descriptive notes of much interest and value. No new species are included. A provisional list of parasitic fungi found in Wisconsin, with a host index, is contributed by J. J. Davis. The list is a long one and does not admit of notes. Edward T. Harper makes another very important contribution to his studies of the larger gill-fungi occurring in the region of the Great Lakes by describing and illustrating very fully and accurately 13 species of *Hypholoma*, including some of the most difficult forms in the family.

Another important contribution to the literature of the chestnut canker recently appeared as Bulletin 347 of the Cornell University Agricultural Experiment Station by P. J. Anderson and W. H. Rankin. This is a very complete treatment of the subject and contains an account of many original investigations and experiments extending over a period of years. Regarding the outlook for the chestnut tree in America the authors make the following statement: "At present we know of nothing that will prevent the extermination of the American chestnut tree. Every measure of control that has been tried has been abandoned north of West Virginia and the Potomac River. Some persons have expressed the belief that nature herself will intervene to prevent destruction of the species; the virulence of the pathogen will abate, the resistance of the host will be increased, or natural enemies—insects or fungous parasites—will destroy, or at least check, the pathogen. Up to the present, however, there has been no indication of relief along any of these lines. But we do not believe that the ingenuity of our scientists has been exhausted; that further research will bring to light some methods of combating the disease is not beyond the limit of probability."

PHILADELPHIA MEETING OF THE PHYTOPATHOLOGICAL SOCIETY

The American Phytopathological Society held its sixth annual meeting in Philadelphia, December 29-January 1. Abstracts of the large number of interesting papers presented at this meeting have already appeared in *Phytopathology*, the official organ of the society. At the business meeting on January 1, the following officers were elected for the ensuing year: President, H. H. Whetzel; Vice-President, W. A. Orton; Secretary-Treasurer, C. L. Shear, Councilor, M. T. Cook.

The retiring president, Dr. Haven Metcalf, ran all the programs on schedule time, which permitted important discussions. He also showed wisdom in grouping papers on the same general subject. This method applied particularly well to the number of "spot diseases" on apple and other fruits, discussed by Waite, Brooks, Fisher, Reed, Martin, and others.

A plant disease survey is being organized by Mr. R. Kent Beattie, of the Bureau of Plant Industry at Washington, its object being to collect and classify all available data on the distribution of plant diseases in the United States. Plant pathologists are urged to send in specimens, which will be checked as to determination and placed in the herbarium for consultation.

Phytopathology, the official organ of the society, was discussed at length by Dr. Jones and others, who emphasized the fact that the time has come when articles of small scientific value cannot be accepted for publication and money must be obtained for good illustrations, either by contributions from the members or from an endowment. It was held to be the duty of American mycologists to see that American papers of merit are illustrated in the very best possible manner.

Special attention may be called at this time to the following papers:

Professor J. C. Arthur reported *Uredo nootkatensis* from Alaska and other parts of the Pacific Coast as a *Gymnosporangium* with repeating spores. The aecial stage of this species is *Aecidium Sorbi*.

Mr. George L. Peltier reported results of extensive experiments with *Rhizoctonia* in America, over 57 strains having been personally investigated. The common species is *Rhizoctonia Solani*.

Mr. E. W. Sinnott outlined a method for the microscopic study of decaying wood, which consisted in softening, imbedding in celloidin, and staining with methyl violet or other differential stain.

Mr. A. G. Johnson discussed the ascigerous stage of *Helminthosporium teres* Sacc. on barley, which was found to be a *Pleospora*. This perfect stage has been reported for *H. gramineum*, but there is no doubt that it is connected with *H. teres* instead.

A very interesting report was made by Dr. L. R. Jones on lightning injury to cotton and potato plants. This accounts for areas that have been observed where the plants died suddenly from no observable cause. One case was mentioned of lightning injury to corn in Kansas.

Mr. W. A. Orton spoke very briefly of the results of the potato study trip of 1914 and stated that no report of the trip as such would be published, but that the important observations and results would be put into available form at an early date. He is planning to have a meeting of those interested in the subject in Maine next August.

Mr. Harry M. Fitzpatrick reported results of his studies on *Eocronartium typhuloides*, a species intermediate between the Auriculariaceae and the higher basidiomycetes. He found it to be a true parasite on mosses. After examining authentic specimens from Europe, he has decided that *E. typhuloides* Atk., *Clavaria muscigena* P. Karst., and *Typhula muscicola* Fries are identical, the last mentioned name being the oldest.

A report by Dr. L. R. Jones on further experiments with fusarium-resistant cabbage proved very interesting. In 1910, the "yellows" was so bad in Wisconsin that most of the cabbages were killed. However, a few survived, which were selected as resistant strains. The process of selection has been continued since that time and Dr. Jones is now ready to distribute seed from these selected strains, which will yield remarkable results, the best yielding 95.5 per cent. of heads and 19 tons per acre, while the commercial strain from which the resistant strain was derived yielded only 17 per cent. of heads and a little over 2 tons per acre. It looks as though the disease produced by *Fusarium conglutinans* might be entirely eliminated by this process of selection.

Mr. W. M. Scott described and discussed a new fungicide which may replace lime-sulfur for spraying fruit trees. It is prepared by using barium instead of calcium in combination with sulfur, which permits the shipment of the fungicide in the dry state. This is much more convenient, while the price should be about the same and the results fully as beneficial. Lime-sulfur mixture is generally used now instead of Bordeaux for orchard work. The yellowish color is not objectionable to fruit trees but makes it impossible for parks. The new substance costs at present 4 cents a pound. The dry crystalline substance consists of 85 per cent. of barium tetrasulfid and a small percentage of barium thiosulfate and free sulfur. When this crystalline substance is dissolved in cold water, preparatory to spraying, some of the free sulfur unites with the tetrasulfid, forming pentasulfid. It has been determined that it is the polysulfid of barium rather than the thiosulfate or free sulfur that is beneficial.

The last paper on the program was by Miss Caroline Rumbold, showing some effects on chestnut trees of the injection of chemicals. Tree injection is difficult because there is no blood in the tree to distribute the chemical, which is apt to go up and down in a restricted area. Openings were made on different sides of the tree trunks and fluids of various compositions and strength were injected through tubes clamped to the trunk. Aniline stains were first used to determine the best methods of injection. No practical results with the chestnut canker were obtained, but it is hoped that some methods will be devised whereby valuable trees may be saved when attacked by diseases beneath the bark.

W. A. MURRILL.

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